ISSN 0377–9335

Vol. 31 December 2006 No. 4

CONTENTS

Department of Zoology, University of Kerala
Kariavattom, Trivandrum, India 695581

ENTOMON

ENTOMON is a quarterly journal of the Association for Advancement of Entomology issued in March, June, September and December, devoted to publication of research work on various aspects of insects and other arthropods.

Address MS and all editorial correspondence to Managing Editor, ENTOMON, Department of Zoology, University of Kerala, Kariavattom, Trivandrum 695581, India.

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ENTOMON 31(4): 251–258 (2006)
Article No. ent.31401

Comparative bionomics of leaf folders, *Cnaphalocrocis medinalis* Guenee and *Marasmia patnalis* Bradley in rice

Padmavathi Ch*, Gururaj Katti, A. P. Padmakumari and I. C. Pasalu

Division of Plant Protection, Directorate of Rice Research, Rajendranagar, Hyderabad 500 030, India
Email: paddi68@rediffmail.com

ABSTRACT: Leaf folder is prevalent in all the rice growing tracts of South and Southeast Asia. Of all the species, *Cnaphalocrocis medinalis* Guenee is the most widespread and dominant one in all the rice agro ecosystems. Recently, another closely related species, *Marasmia patnalis* Bradley has also become a serious concern, particularly in Southern States of India. Detailed observations on biology and morphometry of *M. patnalis vis-a vis C. medinalis* have been covered in this paper. The proportion of *C. medinalis* to *M. patnalis* in the field population was 24:1. *M. patnalis* completed its development from egg to adult in 31 days passing through six instars whereas *C. medinalis* took 24 days for complete development passing through five instars. Morphometry revealed that the head capsule was slightly longer than wide, in case of *M. patnalis* while it was wider than long in *C. medinalis*. Pupa of *M. patnalis* was dark-red in appearance, 9–10 mm long and 1.5 to 1.9 mm wide whereas *C. medinalis* pupa was light brown, 9–11 mm long and 1.75 to 2.25 mm wide.

KEYWORDS: Leaf folder, *Marasmia patnalis*, *Cnaphalocrocis medinalis*, bionomics, rice

INTRODUCTION

Leaf folder is prevalent in all the rice growing tracts in India and other Southeast Asian countries such as Sri Lanka, Philippines and Malaysia. Once considered as a minor pest, it has now attained a major pest status due to the intensification of rice production in these countries. Of the eight species of leaf folders reported, *Cnaphalocrocis medinalis* Guenee is the most widespread and dominant (Khan *et al.*, 1988; Pasalu *et al.*, 2005). Another closely related species, *Marasmia patnalis* Bradley

*Corresponding author

has also emerged as a pest in rice (Dale, 1994). Due to overlapping distribution, close resemblance of larval behaviour and plant damage symptoms, this species is often confused with *C. medinalis*. In India, *C. medinalis* is predominant and widespread, while *M. patnalis* is mainly confined to Southern states. The present paper reports the biology and morphometrics of *M. patnalis vis-a-vis C. medinalis*.

MATERIALS AND METHODS

Field and glasshouse cum laboratory studies were carried out at the Directorate of Rice Research, Rajendranagar, Hyderabad. Adults of the two species collected from the paddy field were the source of insects for various studies. All the studies were carried out under ambient conditions (Temperatures 20–35 °C; Relative humidity 50–85%).

Field studies

Estimation of proportion of species in field

To know the proportion of two leaf folder species existing in the field population, sweepnet collection was done using standard insect net. During each collection, three semicircular sweeps were made in rice field (600 m^2) grown with Taichung Native1 (TN 1) variety, walking diagonally across the field. Adults of the two species collected from the sweepnets were counted and recorded. Three such collections were made to estimate the proportion of the two leaf folder species. Adult moths were identified based on the wing markings described by Barrion and Litsinger (1985). In the same area, 18 quadrants of 1 m^2 were marked for recording the larval population. In each quadrant, larvae and pupae were collected from the damaged or folded leaves and reared in the laboratory. The leaf folder species was confirmed based on the characteristics of adults after emergence.

Glasshouse cum laboratory studies

Comparative biology and development

Adult moths of *C. medinalis* and *M. patnalis* were collected from the field and paired. Five pairs of each species were released separately for oviposition on 20–25 day old TN 1 plants covered with cylindrical mylar cage (45 cm height and 14 cm diameter). One hundred freshly laid eggs along with a portion of leaf were transferred to filter paper discs placed over moist cotton in a Petri dish (9 cm diameter) to study the incubation period and hatching percentage. Neonate larvae (25) were individually transferred to rice leaf placed on moist filter paper in a Petri dish (14 cm diameter). Fresh leaves from 20–25 day old TN1 plants were provided daily as food until pupation. Larval survival and number of moultings were noted. To know the fecundity and oviposition period, newly emerged male and female moths were paired and confined to a potted TN 1 plant covered with mylar cage. Honey solution (20%) was provided as a source of food for adults. The number of eggs laid by each female was recorded.

Comparative morphometrics

Immediately after hatching, neonate larvae of both the leaf folders were transferred to fresh rice leaves placed on a moist filter paper in a Petri dish. Fresh leaves were provided daily as food until pupation. Ten first instar larvae were taken separately and morphometric observations were taken. Similarly, after every moult, 10 larvae were separated and morphometric data like body length of larva and length and width of head capsule were measured with an ocular micrometer under a 20× compound microscope (OLYMPUS BX50). Means and standard errors were computed for various parameters recorded.

RESULTS

Proportion of species in the field

Total numbers of leaf folder moths collected from sweep nets were found to be 425, of which 408 were of *C. medinalis* and 17 of *M. patnalis*. Thus, the proportion of *C. medinalis* to *M. patnalis* was 24: 1 indicating that *C. medinalis* is the predominant species. The larvae of both these species fed from the folded leaves showed similar damage symptoms. Out of 360 larvae and pupae collected and reared, 342 were confirmed as *C. medinalis* and 18 as *M. patnalis*. The proportion of *C. medinalis* larvae to *M. patnalis* larvae was 19:1 indicating that the proportion of *M. patnalis* was higher at larval stage than at adult stage.

Comparative biology and development

Oviposition and fecundity

Female moths of *M. patnalis* laid eggs singly or in groups of 2–9, mainly on the upper leaf surface towards the tip of the leaf. Groups of two eggs were very common. *C. medinalis* females deposited eggs singly or in semi-clusters of 3–8 on the upper surface near to veins. Single eggs were very common. Fecundity ranged from 96 to 109 with an average of 102.8 incase of *M. patnalis* and 135 to 175 with an average of 155 in *C. medinalis*. Incubation period of *M. patnalis* varied from 2.5 to 4.5 days with a mean of 3.6 days (Fig. 1) and 72% eggs hatched. In the case of *C. medinalis* incubation period varied between 3.5 and 4.2 days with an average of 3.8 days and 75% eggs hatched. In both the species, eggs turned black prior to hatching. Pre-oviposition period of 3 days and oviposition period of 4 days was observed in both the species.

Larval development

Developmental period for *M. patnalis* larva ranged from 17 to 21 days with an average of 19 days. Larva passed through six instars whereas *C. medinalis* completed its larval development in 14 days after passing through five instars (Fig. 1). The nature of feeding and damage symptom were similar in both the species. Immediately after hatching, neonate larvae moved to the unopened leaf at the center of the plant and fed gregariously by scraping the green matter. From second instar onwards, the larvae

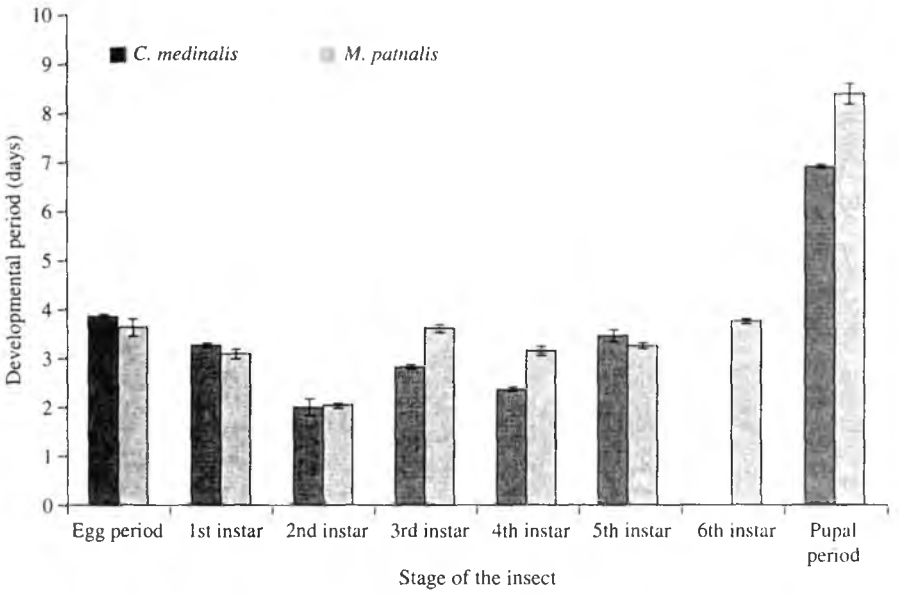


FIGURE 1. Comparative biology of two leaf folder species in rice.

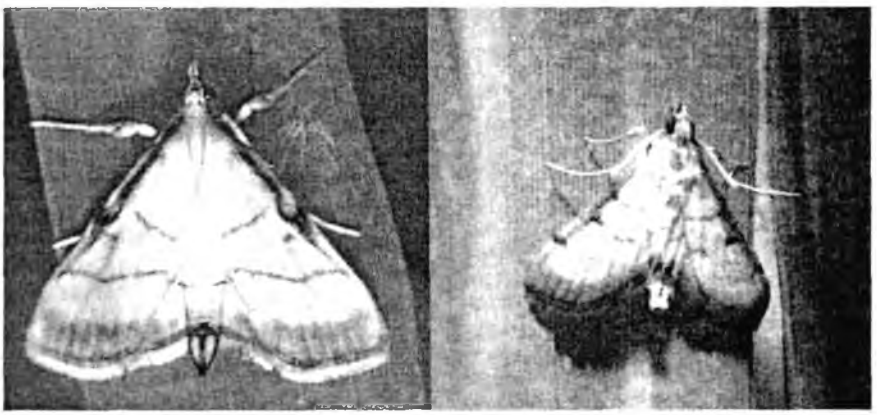
folded the leaves by stitching with silken threads keeping open both the ends of the fold. Larval feeding by scraping the green matter staying within the fold resulted in the development of longitudinal white streaks. Sometimes 2–3 leaves were stitched together and larvae fed from within this fold.

Pupation and pupal development

M. patnalis larva pupated mostly by stitching two to three leaves together. Pupal period ranged from 8 to 9.5 days with an average of 8.5 days. *C. medinalis* larva turned pinkish white just before pupation. The larva cut the leaf margin transversely up to the midrib, folded the cut portion of the leaf lamina over the other half and pupated inside the white silken webbing in leaf fold after stitching it completely on all sides. Pupation occurred mostly at the base of the plant and a single leaf was folded for pupation. Pupal period ranged from 6 to 8.5 days with an average of 7 days. Adult emergence and mating occurred mostly at night. Female longevity was 8 days in *M. patnalis* and 9 *days* in *C. medinalis*. Male to female ratio was 2:1 in case of *M. patnalis* and 1:1.14 in *C. medinalis*.

Total developmental period

M. patnalis total developmental period from egg to adult ranged from 28.9 to 35 days with an average of 31 days passing through six instars whereas *C. medinalis*



(a) *Cnaphalocrocis medinalis* (b) *Marasmia patnalis*

FIGURE 2. (a) *Cnaphalocrocis medinalis*; (b) *Marasmia patnalis*.

developmental period ranged from 22.1 to 25.8 days with an average of 24.8 days after passing through five instars (Fig. 1), under same ambient conditions.

Comparative morphometrics

Characteristics of different instars along with morphometry of both the species are given in Table 1. *M. patnalis* larvae were slender and smaller in size compared to *C. medinalis*. Morphometry revealed that the head capsule was slightly longer than wide in case of *M. patnalis* whereas it was wider than long in *C. medinalis*. Though it is difficult to distinguish between both these species, certain characteristic features help to identify the instars. Larva of *M. patnalis* was yellowish green with faint markings, while *C. medinalis* was dark with black patches on thoracic and abdominal regions. Pupa of *M. patnalis* was dark-red in appearance, 9–10 mm long and 1.5 to 1.9 mm wide, whereas in *C. medinalis*, it was light- brown, 9–11 mm long and 1.75–2.25 mm wide.

C. medinalis moth was golden yellow in colour with brown margins on both the wings. There were three bands traversing entire forewing. Middle band was short, comma like and curved outside (Fig. 2a). *M. patnalis* moth was dull yellow with brown costa and brownish yellow anal and cubital areas. The forewings bear three median prominent lines; the post-median line moves inward towards the bottom half of the incomplete median line and runs straight downward. The inner median line runs straight from the costal to anal area (Fig. 2b). Male moths of both the species have prominent patch of dark brown andraconial scales along the midcosta of forewing. The adults of both species could also be distinguished based on their size and resting position. *M. patnalis* adults are smaller than *C. medinalis* adults. While at rest, *C. medinalis* adult appears triangular in shape whereas *M. patnalis* wings get stretched forming wedge shape.

TABLE 1. Morphometric and morphological differences of larvae of two species of leaf folders

Instar	Name of the species	Length of the larva (mm)*	Head capsule		Characteristics
			Length (mm)*	Width (mm)*	
I	*C.m*	1.85 ± 0.04	0.19 ± 0.007	0.20 ± 0.018	Light cream body with black head
	M.p	1.30 ± 0.04	0.14 ± 0.009	0.12 ± 0.006	Creamish white body with light brown head
II	*C.m*	3.20 ± 0.07	0.45 ± 0.015	0.47 ± 0.007	Light green larva with brown head
	M.p	2.10 ± 0.08	0.30 ± 0.021	0.28 ± 0.008	Yellowish green larva with a small light brown marking on the thoracic dorsum
III	*C.m*	6.30 ± 0.09	0.55 ± 0.019	0.60 ± 0.025	Pair of semi-circular brownish patches on mid-dorsal line of pronotum
	M.p	3.20 ± 0.06	0.43 ± 0.010	0.39 ± 0.005	Yellowish green larva with faint markings on the thoracic region
IV	*C.m*	9.50 ± 0.37	0.78 ± 0.008	0.82 ± 0.010	Patches on prothoracic segment turn black. Similar patches also visible on last abdominal segments
	M.p	6.70 ± 0.16	0.65 ± 0.024	0.60 ± 0.023	Light brown patches found on abdominal segments
V	*C.m*	14.00 ± 0.47	1.03 ± 0.006	1.10 ± 0.039	Light green larva with brown head. Pro, meso, metathorax and last abdominal segments bear black patches
	M.p	9.50 ± 0.28	0.84 ± 0.009	0.80 ± 0.033	Yellowish green larva with a pale brown head, five brownish patches on thoracic and abdominal segments
IV	*M.p*	12.50 ± 0.29	0.95 ± 0.038	0.90 ± 0.018	Yellowish green larva with a pale brown head and prothoracic shield and faint markings

*Mean ±Standard error.
C.m = Cnaphalocrocis medinalis M.p = Marasmia patnalis

DISCUSSION

The present study is the first report on the biology and morphometrics of *M. patnalis* in India. Joshi *et al.* (1985) studied the life cycle of *M. patnalis* in Philippines and reported that the larva passed through six instars in 23 days. Total duration of development averaged 37 days whereas in our study, *M. patnalis* took 19 days for larval development passing through six instars and total duration of development averaged 31 days.

Earlier workers reported variation in the developmental period of egg, larva and pupa from region to region and *C. medinalis* life cycle ranged from 24 to 41 days (Lingappa, 1972; Yadava *et al.*, 1972; Velusamy and Subramaniam, 1974; Godase and Dumbre, 1982). In the present study, *C. medinalis* completed its development from egg to adult in 24.8 days at temperatures ranging between 20 and 35°C Wada and Kobayashi (1980) reported similar results, the length of the life cycle of *C. medinalis* ranging from 21 to 28.6 days at above temperatures in Japan. The larva passed through five instars in 14 days with an average duration of 3.2, 2.0, 2.8, 2.4 and 3.5 days, respectively. This is in corroboration with the results of Lingappa (1972); Velusamy and Subramaniam (1974); Wada and Kobayashi (1980), whereas Rajamma and Das (1969) reported that the larva passed through six instars in 24.2 days with an average duration of 3, 3, 5, 3.8, 4 and 5.4 days, respectively. In the Philippines, developmental period ranged from 25 to 52 days with an incubation period of 3 to 6 days, larval period 15 to 36 days and pupal period 6 to 9 days (Pathak, 1975; Barrion *et al.*, 1991).

It is evident from the above study that *C. medinalis* is the dominant species co-existing with *M. patnalis* in this region. This may be due to shorter duration of the life cycle in *C. medinalis* with five larval instars compared to six in *M. patnalis*. Generally under field conditions it is difficult to distinguish between these two species. The larval and pupal morphometrics and characteristic features reported in this paper will help in correct identification of the species. The study also indicates the need for a continuous monitoring of species composition of leaf folders in the wake of its significance in the changing pest scenario of rice.

ACKNOWLEDGEMENTS

The authors are highly thankful to the Project Director, Directorate of Rice Research, Hyderabad for providing necessary facilities.

REFERENCES

Barrion, A. T. and Litsinger, J. A. (1985) Identification of rice leaf folders (LF) by wing markings. *International Rice Research Newsletter* **10**: 24.

Barrion, A. T., Litsinger, J. A., Medina, E. B., Aguda, R. M., Bandong, J. P., Pantua, P. C., Viajante, V. D., de la Cruz, C. G., Vega, C. R., Soriano, J. S., Camanag, E. E., Saxena, R. C., Tryon, E. H. and Shepard, B. M. (1991) The rice *Cnaphalocrocis* and *Marasmia* (Lepidoptera: Pyralidae) leaf folder complex in the Philippines: taxonomy, bionomics and control. *Philippine Entomologist* **8**: 987–1074.

Bradley, J. D. (1981) *Marasmia patnalis* sp.n (Lepidoptera: Pyralidae) on rice in South East Asia. *Bulletin of Entomological Research* **71**: 323–327.

Dale, D. (1994) Insect pests of the rice plant – their biology and ecology. In: *Biology and Management of Rice Insects*, Heinrichs, E. A. (Ed). Wiley Eastern Limited and International Rice Research Institute: 363–485.

Godase, S. K. and Dumbre, R. B. (1982) Laboratory studies on bionomics of rice leaf folder, *Cnaphalocrocis medinalis* (Lepidoptera: Pyralidae). *Pestology* **6**: 13–16.

Joshi, R. C., Medina, E. and Heinrichs, E. A. (1985) Life cycle of *Marasmia patnalis*, a rice leaf folder in the Philippines. *International Rice Research Newsletter* **10**: 15–16.

Khan, Z. R., Barrion, A. T., Litsinger, J. A., Castilla, N. P. and Joshi, R. C. (1988) A bibliography of rice leaf folders (Lepidoptera: Pyralidae). *Insect Science & its Application* **9**: 129–174.

Lingappa, S. (1972) Bionomics of the rice leaf folder, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Mysore Journal of Agricultural Sciences* **6**: 123–134.

Pasalu, I. C., Gururaj, Katti, Krishnamurthy, P., Subba Rao, L. V., Reddy, C. S., Subbaiah, S. V., Krishnaiah, N. V. and Prasad, J. S. (2005) *Integrated Pest Management in Rice*, Technical Bulletin No. 15. Directorate of Rice Research: Rajendranagar, Hyderabad, p. 53.

Pathak, M. D. (1975) *Insect Pests of Rice*, International Rice Research Institute: Los Banos, Philippines, p. 68.

Rajamma, P. and Das, N. M. (1969) Studies on the biology and control of rice leaf roller, *Cnaphalocrocis medinalis* Guenee. *Agricultural Research Journal of Kerala* **7**: 110–112.

Velusamy, R. and Subramaniam, T. R. (1974) Bionomics of the rice leaf roller, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Indian Journal of Entomology* **36**: 185–189.

Wada, T. and Kobayashi, M. (1980) Effects of temperature on development of the rice leaf roller, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Applied Entomology and Zoology* **5**: 207–214.

Yadava, C. P., Santaram, G., Israel, P. and Kalode, M. B. (1972) Life-history of rice leaf roller, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae) and its reaction to some varieties and grasses. *Indian Journal of Agricultural Sciences* **42**: 520–523.

(Received 21 February 2006; accepted 27 November 2006)

ENTOMON **31(4):** 259–266 (2006)
Article No. ent.31402

Pathogenicity of three species of EPN against cotton bollworm *Helicoverpa armigera* Hub

B. Dhara Jothi*[1] and Usha K. Mehta[2]

[1]*Central Institute for Cotton Research, Regional Station, Coimbatore 641003, India*
[2]*Sugarcane Breeding Institute, Coimbatore 641007, India*

ABSTRACT: Three species of Entomopathogenic nematodes namely *Heterorhabditis indica, H. bacteriophora* and *Steinernema glaseri* were tested for the pathogenicity against *Helicoverpa armigera* Hub. Among the three species of nematodes *S. glaseri* was more virulent in causing maximum mortality, followed by *H. indica* and *H. bacteriophora*. Third instar larvae was highly susceptible followed by fourth and fifth instars. An inoculum level of 80IJS/larva caused 100 per cent mortality, the late instar larvae and the Heterorhabditid species contributed to more progeny production.

KEYWORDS: *Helicoverpa armigera*, *Heterorhabditis indica*, *H. bacteriophora*, *S. glaseri*, pathogenicity, infective juveniles

INTRODUCTION

Helicoverpa armigera Hub is a serious pest on cotton, causing extensive and economic damage in different ecological zones. *Helicoverpa* species are polyphagous insects damaging 60 cultivated plant species belonging to 39 natural orders found in Africa, Asia and Australia (Anon, 1993).The major cultivated crops damaged and devastated by these species are cotton, sorghum, safflower, tobacco, tomato, bhendi etc. Hence a critical strategy is needed for managing this serious pest. There is a growing interest in the use of entomopathogenic nematodes in the families Steinernematidae and Heterorhabditidae as bio-control agents, which are considered as alternative measures to chemical control of insect pests (Gaugler, 1981; Kaya, 1985; Poinar, 1986). In some cases, nematode treatment provided levels of insect control equivalent to those of chemical insecticides (Georgis, 1990). The infectivity of these nematodes is different depending on nematode species and development stage of insects. (Glazer and Navon, 1990). Hence this study was conducted to (i) to determine the pathogenicity of *H. indica*, *H. bacteriophora*, and *S. glaseri* against *H. armigera*. (ii) to record the progeny production of IJS per dead larva in response to nematode concentration.

*Corresponding author

MATERIALS AND METHODS

The infective juveniles (IJS) of *H. indica, H. bacteriophora* and *S. glaseri* were obtained from nucleus culture maintained in the section of Nematology of Sugarcane Breeding Institute, Coimbatore. The basic in-vivo production method outlined by Woodring and Kaya (1988) was followed for the further multiplication of nematodes by using *Galleria mellonella* as laboratory host. Following harvest, the nematodes were transferred to 250 ml canted neck Corning tissue culture flasks as 10,000–20,000 IJs/ml and stored at 15 ± 1°C in a BOD incubator with a liquid depth of one cm or less. Cotton bollworm *H. armigera* larvae were collected from the field and maintained on artificial diet according to the methods described by Armes *et al.* (1992).

Pathogenicity of the three nematodes species against the three different instars was determined through sand bioassay method. Fourty larvae of III, IV and V instars of *H. armigera* were surface sterilized once in 1% formalin and thrice with 0.1% formalin solution and placed individually in the cell well trays and packed with sterile sand with a moisture of 18% (w/w). Different inoculum levels namely 1, 5, 10, 20, 40, 80 and 100 IJS of *H. indica, H. bacteriophora* and *S. glaseri* were inoculated into the individual well with a pipettemann and incubated at 25 °C. The experiment was conducted in Factorial Randomized block design (Panse and Sukhatme, 1967). Each treatment was replicated four times with 10 larvae/replication tested. Twenty four hours after inoculation, observations were recorded on the time taken for each nematode species to cause mortality of the different larval instars of the host and the percentage of host mortality. The number of IJS production per larva was estimated as per the method described by (Capanillas and Raulston, 1994).

Five pupae of *H. armigera* were placed at different depth *viz.*, 2.5, 5.0 and 7.5 cm in the moist sterile soil in individual plastic pots 12 cm × 10 cm size for each depth. The final soil moisture was 13% w/w water potential. Each treatment was replicated four times. Four different dosages *viz.*, 250, 500, 750 and 1000 IJS in 10 ml of water were added to different pots respectively. The infected pupae were recovered after 24 h, rinsed in water, placed in a petridish and kept at 100 per cent RH inside with wet paper towels. Two days later dead pupae were dissected and checked for nematode entry. Five dead pupae from each treatment replication were placed on white trap for recording productivity.

The data on percent mortality of larvae were transformed to their corresponding angles (Arc Sine percentage) after converting zero values into 0.1. Similarly data on multiplication of IJs were transformed to square root values.

RESULTS

The evaluation of three species of entomopathogenic nematodes against three different larval instars of *H. armigera* indicated that 72 hours after inoculation *S. glaseri* was more virulent in causing a maximum mean mortality of 83.05 per cent, *H. indica* recorded 72.21 with 62.77 followed by *H. bacteriophora* (Table 1).

TABLE 1. Mortality of *H. armigera* exposed to varying doses of entomopathogenic nematodes and the infective juvenile production observed 72 hrs after treatment

EPN	Dose	Mortality (%)*				Infective juvenile production per larva#			
		III instar	IV instar	V instar	Mean	III instar	IV instar	V instar	Mean
H. indica	1	66.66 (54.99)	33.33 (34.63)	26.66 (30.78)	42.21	5118.33 (71.53)	7700.66 (87.74)	9616.00 (98.04)	7478.33
	5	80.00 (68.00)	53.33 (47.30)	40.00 (39.23)	57.77	9388.33 (96.86)	23338.33 (148.46)	22307.00 (149.40)	18344.55
	10	100.00 (89.80)	73.33 (59.21)	60.00 (50.77)	77.77	12513.33 (111.84)	23338.33 (152.75)	25422.00 (159.40)	20424.55
	20	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	14036.00 (118.47)	28977.66 (170.22)	31400.66 (177.18)	24804.77
	40	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	22313.33 (149.34)	37133.00 (192.67)	38673.33 (196.65)	32706.55
	80	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	24227.33 (155.64)	41159.66 (202.86)	43869.33 (209.44)	36418.77
	100	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	29428.66 (171.53)	44251.33 (210.35)	47959.33 (218.99)	40546.44
	Control	0.00 (0.19)	0.00 (0.19)	0.00 (0.19)	0.00	0.00 (0.03)	0.00 (0.03)	0.00 (0.03)	0.00
	Mean	80.83	69.99	65.83	72.21	14628.16	25737.37	27405.95	22590.49
H. bacteriophora	1	20.00 (26.56)	26.66 (30.78)	20.00 (26.56)	22.22	2789.00 (52.79)	6702.66 (81.86)	965.00 (31.06)	3485.55
	5	33.33 (35.01)	33.33 (35.01)	53.33 (46.92)	39.99	7225.00 (84.99)	8780.66 (93.69)	19170.66 (138.43)	11725.44
	10	53.33 (46.92)	46.66 (43.07)	66.66 (54.99)	55.55	9901.33 (99.50)	11442.00 (106.92)	30494.66 (174.61)	17279.33
	20	93.33 (76.79)	80.00 (63.43)	80.00 (63.43)	84.44	16237.66 (127.37)	36209.66 (190.27)	38351.66 (195.80)	30266.33
	40	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	29918.00 (172.96)	39262.33 (198.14)	45095.00 (212.26)	38091.77

TABLE 1. (Continued)

EPN	Dose	Mortality (%)*				Infective juvenile production per larva#			
		III instar	IV instar	V instar	Mean	III instar	IV instar	V instar	Mean
	80	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	29918.00 (172.96)	43643.33 (208.74)	46824.00 (216.37)	40128.44
	100	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	38241.00 (195.53)	48961.66 (221.26)	49380.00 (222.20)	45527.55
	Control	0.00 (0.19)	0.00 (0.19)	0.00 (0.19)	0.00	0.00 (0.03)	0.00 (0.03)	0.00 (0.03)	0.00
	Mean	62.49	60.83	64.99	62.77	16778.75	24375.29	28785.12	23313.05
S. glaseri	1	93.33 (81.01)	100.00 (89.80)	66.66 (54.99)	86.66	352.66 (16.47)	277.66 (16.66)	602.66 (24.51)	411.00
	5	93.33 (81.01)	100.00 (89.80)	73.33 (59.21)	88.88	495.66 (22.25)	428.00 (20.93)	1145.33 (33.79)	689.66
	10	100.00 (89.80)	100.00 (89.80)	80.00 (63.43)	93.33	5563.00 (72.99)	6251.66 (79.02)	7749.33 (88.02)	6521.22
	20	100.00 (89.80)	86.66 (72.22)	100.00 (89.80)	95.55	6813.00 (82.53)	10710.00 (103.48)	13126.66 (114.54)	10216.55
	40	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	9468.66 (97.30)	12106.66 (110.02)	14514.33 (120.45)	12029.88
	80	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	12252.33 (110.64)	19012.66 (137.87)	21122.33 (145.31)	17462.44
	100	100.00 (89.80)	100.00 (89.80)	100.00 (89.80)	100.00	14200.33 (119.14)	24486.33 (156.47)	30400.00 (174.33)	23028.88
	Control	0.00 (0.19)	0.00 (0.19)	0.00 (0.19)	0.00	0.00 (0.03)	0.00 (0.03)	0.00 (0.03)	0.00
	Mean	85.83	85.83	77.49	83.05	6143.20	9159.12	11082.54	8794.95
SEd ±		**1.00**	**1.63**	**1.00**	**4.91**	**151.92**	**248.09**	**151.92**	**429.71**
CD (p=0.05)		**1.98**	**3.24**	**1.98**	**9.74**	**301.47**	**492.31**	**301.47**	**852.70**

*Values in parentheses are arc sine transformed values; #Values in parentheses are square root transformed values

The mean percentage of mortality of all the three instars by three species of nematodes indicated that among the three instars a maximum mortality of 85.33, 80.83 and 62.77 on III instar, 85.83, 69.99 and 60.83 on IVth instar and 77.49, 65.83, and 64.99 on Vth instar by *S. glaseri*, *H. indica* and *H. bacteriophora*, respectively. Age of the larvae and the percent mortality caused by three species of nematodes were negatively correlated except the mortality caused by *H. bacteriophora* was higher on Vth instar followed by III and IVth instars, respectively.

Lower doses of *H. bacteriophora viz.*, 1, 5, 10 and 20 IJS/ml caused minimum mortality on IIIrd instar when compared to the other species. *S. glaseri* caused maximum per cent of mortality in all the doses ranging from 93.33–100, 86.66–100 and 66.66–100 on III, IV and Vth instars, respectively (Table 1).

All the inoculum levels were superior than the control. As the inoculum level increased the mortality range also increased. However 40 to 100 IJs/ml of *H. bacteriophora*, and *S. glaseri* 20 to 100 IJs/ml of *H. indica* caused cent per cent mortality and were on par with each other.

Among three species of EPN tested *S. glaseri* recorded the minimum mean IJs production (8794.95 IJs/larva) followed by *H. indica* (22590.49 IJs/larva) and *H. bacteriophora* (23313.05 IJs/larva) which were also on par. However, on IIIrd and Vth instar *S. glaseri* recorded 6143.20–11082.54 IJs per larva followed by *H. indica* (14628.16–27405.95 IJs/ larva) and *H. bacteriophora* (16778.75–28785.12 IJs/ larva). As the inoculum level increased, corresponding increase in the IJs productivity was recorded (Table 1).

DISCUSSION

H. armigera has been selected for detailed studies of pathogenicity as it is important pest of cotton, especially in this region. While recording the pathogenic effect of three species it was noted that *S. glaseri* was highly virulent in causing maximum mean mortality followed by *H. indica* and *H. bacteriophora* which were on par with each other. In an experiment Vyas and Yadav (1992) proved that *S. glaseri* was highly pathogenic against soil dwelling Lepidopteran pests such as *S. litura*. Also Sosa and Beavers (1988) reported that on sugarcane white grub, *Ligyrus subtropicus* (Blatchlay) similar results were expressed wherein *S. glaseri* caused higher mortality than *S. feltiae* and *H. heliothidis* when applied at 5000 nematode per larva.

The results on susceptibility level of different instars of the host showed that the nematode caused significantly higher mortality in III instar larvae of *H. armigera* followed by IV and V instar. Similar work on host instar larvae of *Spodoptera litura* and *H. armigera* by Razak (1989) also show that the final instar larvae were less susceptible to *S. feltiae* compared to III instar.

The experiments conducted by Choo *et al.* (1991) on forest insects also revealed similar results where they found that the mortality expressed by the larvae of *A. coerulea* exposed to different doses of *S. carpocapsae* was 85.4–100 per cent for I instar larvae, 80–100 per cent for II instar larvae. The mortality of I, II and III instar

larvae of *A. coerulea* to the exposed doses of *H. bacteriophora* was 82.5–100 per cent, 77.5–100 per cent and 55–100 per cent respectively.

Effect of inoculum level on mortality of *H. armigera* in the present studies showed that as the inoculum level increased the mortality level also increased 72 hrs after exposure in all the three species. Earlier Karunakar (1990) in a study on the parasitism of III instar of white grub under different dosage levels of *S. glaseri* and *H. indica* has also expressed the same results. Sosa and Beavers (1988) also found that as the inoculum level of *S. glaseri* increased the per cent mortality of white grub also increased. Molta and Hominick (1989) have also reported a positive linear correlation between mortality of *Acdges aegypti* and dosage of *S. feltiae* and *H. heliothidis*.

In the studies on the production of infective juveniles, *H. bacteriophora* recorded maximum production while the minimum production was shown by *S. glaseri*. These results are comparable with the findings of Mannon and Jansson (1992) in their studies where they found that the first generation Heterorhabditid nematodes are Hermaphroditic, which is likely to contribute to more progeny production than Steinernematid nematodes.

The level of average IJ production per instar was recorded as maximum in the V instar larvae followed by IV instar larvae and minimum production was recorded from III instar larvae. This observation is supported by the findings of Fujiie *et al.* (1993) that production of nematode juveniles increased with increase in insect size. Infectivity rate of entomopathogenic nematode to the pupae of *H. armigera* was tested in the soil. Between the three different soil depths tested 2.5 cm, 5.0 cm and 7.5 cm, all the inoculum levels of entomopathogenic nematodes 250, 500, 750 and 1000 IJS/pupae were found to be effective in infecting the pupae at 2.5 cm and 5.0 cm causing 100 per cent mortality while no mortality was recorded at 7.5 cm. Productivity of IJS from the infected pupae were directly related with the inoculum level and the depth at which the host was tested. Soil being the natural habitat of the nematodes, they are able to move in search for the host. The results of these studies are in confirmation with findings of Kondo and Ishibashi (1984) who noted that the infection efficiency of *S. feltiae* (DD-136) to the common cut worm, *S. litura* (Lepidoptera: Noctuidae) in the soil indicated that nematodes infectivity also decreased with increasing inoculation depth. Hence depth to which the IJS can move becomes important in the case of *H. armigera*, which pupates in the soil.

Thus, the present studies clearly indicated that, the early instars are highly susceptible than late instars. In general, the early stages are active feeders, which would have facilitated for more nematode entry and this may be the probable reason for their high susceptibility. Hence, this stage may be considered as the critical stage in the management of *H.armigera* by using EPN.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, Sugarcane Breeding Institute for all the facilities provided and to the Director, Central institute for Cotton research, Nagpur for the kind encouragement.

REFERENCES

Anon, (1993) *Technical Bulletin of Central Institute for Cotton Research*, Regional Station, Coimbatore, p. 7.

Armes, N. J., Bond, G. S. and Cooter, R. J. (1992) The laboratory culture and development of *Helicoverpa armigera* Hubner. In: *Natural Resource Institute Bulletin*, NRI: Chattam, U.K., p. 57.

Cubanillas, H. E. and Raulston, J. R. (1994) Pathogenicity of Steinernema riobravis against corn earworm, *Helicoverpa zea* (Boddie). *Fundamental and Applied Nematology* **17(3)**: 219–223.

Choo, H. Y., Kaya, H. K., Lee, S. M., Kim, T. O. and Kim, J. B. (1991) Laboratory evaluation of entomopathogenic nematodes, *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* against some forest insect pests. *Korean Journal of Applied Entomology* **34(4)**: 227–232.

Fujiie, A., Yokoyama, T., Sawada, M. and Hasegawa, M. (1993) Pathogenicity of an entomogenous nematode, *Steinernema kushidai* (Nematoda: Steinernematidae), on *Anomala cuprea* (Coleoptera: Scarabaeidae). *Japanese Journal of Applied Entomology and Zoology* **37(2)**: 53–60.

Gaugler, R. (1981) Biological control potential of Neoaplectana nematodes. *Journal of Nematology* **13**: 241–249.

Georgis, R. (1990) Formulation and application technology. In: *Entomopathogenic Nematodes in Biological Control*, Gaugler, R. and Kaya, H. K. (Eds). CRC Press: Boca Raton, Florida, 173–191.

Glazer, I. and Navon, A. (1990) Activity and persistence of entomoparasitic nematodes tested against *Heliothis armigera* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* **83**: 1795–1800.

Karunakar, G. (1990) Studies on Entomophilic nematodes for the control of two species of sugarcane white grubs *Ph.D.Thesis*, Tamil Nadu Agricultural University, Coimbatore, (submitted)

Kaya, H. K. (1985) Entomogenous nematodes for insect control in IPM systems, in biological control. In: *Agricultural IPM System*, M. A., Hoy and Herzog, D. C. (Eds). Academic Press: Orlando, p. 283.

Kondo, E. and Ishibashi, N. (1984) Infection and multiplication of *Steinernemafertiae* (Str. mexican) on the common cutworm *Spodopteralitura*. *Japanese Journal of Applied Zoology and Entomology* **28**: 229–236.

Mannon, C. M. and Jansson, R. K. (1992) Comparison of ten entomopathogenic nematodes for control of sweet potato weevil (Coleoptera: Apionidae). *Journal of Economic Entomology* **85(5)**: 1642–1650.

Molta, N. B. and Hominick, W. M. (1989) Dosage and time response assessment of *Heterorhabditis heliothidae* and *Steinernema feltiae* (Nematoda: Rhabditidae) against *Aedes aegypti* larvae. *Entomophaga* **34**: 485–493.

Panse, V. G. and Sukhatme, P. C. (1967) *Statistical Methods for Agricultural Workers*, ICAR: New Delhi, p. 328.

Poinar, G. O. Jr. (1986) Entomophagous nematodes. In: *Biological Plant and Health Protection*, Franz, J. M. and Fischler, G. (Eds). Verlag: Stuttgart, p. 95.

Razak, T. A. (1989) Studies on the influence of temperature on the infectivity and multiplication of *Steinernema feltiae* Filipjev (DD-136) and its virulence on *Spodoptera litura* (Fab.) and *Heliothis armigera* (Hub) *M.Sc. (Ag.) Thesis*, Tamil Nadu Agricultural University, Coimbatore, p. 70.

Sosa, O. Jr and Beavers, J. B. (1988) Entomogenous nematode as biological control organism for *Ligyrus subtropicus* (Coleoptera: Scarabacidae) in sugarcane. *Environmental Entomology* **14**: 80–82.

Vyas, R. V. and Yadav, D. N. (1992) Infectivity of entomopathogenic nematode *Steinernema glaseri* on two soil dwelling Lepidopteran. *Annals of Biolology* **8(1)**: 59–63.

Woodring, J. L. and Kaya, H. K. (1988) Steinernematid and Heterorhabditid nematodes. In: *A Hand Book of Biology and Techniques*, Arkansas Agricultural Experiment Station Fayetteville: Arkansas, p. 28.

(Received 31 January 2006; accepted 11 December 2006)

ENTOMON 31(4): 267–275 (2006)
Article No. ent.31403

Effects of Neem-based insecticides on metamorphosis, haemocytes and reproductive behavior in the red cotton bug, *Dysdercus koenigii* Fabr. (Heteroptera: Pyrrhocoridae)

R. K. Tiwari[1], J. P. Pandey[1] and Dinesh Kumar*[2]

[1]*Department of Zoology, KN Govt. Postgraduate College, Gyanpur 221304, India*
[2]*Department of Zoology, Banaras Hindu University, Varanasi 221005, India*
Email: dines1953@yahoo.com

ABSTRACT: The neem-based insecticides (NBIs) (nimbecidine, neemazal and multineem) were topically applied on to *Dysdercus koenigii* to see their bioefficacy. All the NBIs caused prolongation of nymphal period, ecdysial stasis and development of adultoids and imagoes with varied degree of deformities. In addition, mating, fecundity and hatching were affected. The NBI also caused reduction in total haemocytes count, their necrosis and disturbed their normal percentage distribution.

KEYWORDS: neem-based insecticides, metamorphosis, fecundity, haemocytes, *Dysdercus koenigii*

INTRODUCTION

Neem-based insecticides (NBIs) are known to possess several adverse biological effects on insects like repellency, antifeedancy, growth regulatory activity, antifecundity and prothoracicotropic hormone inhibitory activity (Schmutterer, 1990; Medina *et al.*, 2004). Azadirachtin, one of the active ingredients of NBI, affects the haemocytes also (Azambuja *et al.*, 1991; Sharma *et al.*, 2003). The haemocytes contribute a lot in molting, transport of nutrients and hormones and immunity (Takeda, 1977). So far our knowledge regarding the effect of NBI on the haemocytes and other physiological functions like metamorphosis and reproductive behavior is limited. The present study is an attempt to unravel the effects of NBI on haemocytes, molting, and reproductive behavior of *Dysdercus koenigii*.

*Corresponding author

MATERIALS AND METHODS

The laboratory cultures of *D. koenigii* were maintained in BOD incubator according to Venugopal and Kumar (1997). NBI used in the present study were Nimbecidine (0.03% Azadirachtin, Neem oil 90.57%, hydroxyl 5%, epichlorohydrate 0.5%, aromax 3%); Neemazal T'S (Azadirachtin 1%, other limonoids 3%, oil fatty acids glycerol esters 46.3%, polyethylene monosorbitol oleate 49.7% -EID Parry India Ltd.), and Multineem (seed extract containing 0.03% Azadirachtin- Multiplex Fertilizers Pvt. Ltd., Bangalore, India). To examine their effects on haemocytes, molting and reproductive behavior, various concentrations (0.25%, 0.5%, 1% and 2.5%) of these insecticides were prepared by diluting with acetone. The diluted insecticides were applied topically in different doses (see Tables) with the help of glass micropipette on the eggs and dorsal and ventral surfaces of body (cephalic, thoracic and abdominal regions) of nymphs and adults of various age groups. For total haemocytes count (THC) and differential haemocytes count (DHC), 24 h old 5th instar nymphs and adults were treated with NBI. The controls were acetone treated. The blood was drawn after 24 h of treatment. The haemolymph collection, smear formation, staining and counting of cells (THC and DHC) was done as follows. The haemolymph was collected from the cut end of antenna or leg into a small thoma blood cell pipette up to its 0.5 mark and diluted up to 11th mark with Tauber-Yeager's fluid. The diluted blood was transferred on to a standard haemocytometer and the THC was made under a phase contrast microscope. The mean number of circulating haemocytes per mm^3 was calculated using the formula of Jones (1962). For DHC, haemolymph smears were made on clean glass slides having 2–3 drops of 2% glacial acetic acid. The air dried slides having blood smear were stained with 1% Giemsa or Gentian Violet. At least 200 cells of different types were selected from the experimental and control groups separately. Percentage of different cell types was calculated (Pandey and Tiwari, 2005). The effects of NBI were also observed using other parameters like mating, hatching, fecundity and molting. The various developmental stages used were 3 days old eggs, 3 days old (late) 3rd, 4th and 5th instars each and 0 day and 3 days old imagoes.

RESULTS

Effects on molting and metamorphic development

Application of NBI on ventral surface of cephalic and thoracic regions was more effective than application on the dorsal surface of abdominal region, in terms of reduction in longevity of adults. The application of lower doses of NBI caused swift movement in the treated insects; while the higher doses stopped their movement immediately for a moment before they achieved normal movement.

The various doses and concentrations of NBI applied on the dorsal surface of insects' abdomen resulted in varied effects on molting, wing development, mating, fecundity and egg hatchability (Table 1). This reveals that NBI caused complete, partial or incomplete ecdysial stasis by resulting in prolongation of 4th instar; by yielding imagoes with deformed wings and exuviae attached to posterior body end; or

TABLE 1. Effects of neem-based insecticides on moulting, mating, fecundity and egg hatching in *D. koenigii*

Insecticide	Stage	Concentration (%)	Dose (μl)	No. Treated	Effects on			
					Molting/hatching	Mating	Fecundity (No. of eggs)	(%) hatching
Nimbecidine	III nymph (late)	0.5	5	25	Inhibited in 16 nymphs which died after 3 days, 9 molted in IV instar and died after 3 days	—	—	—
	IV nymph (late)	0.5	5	20	All nymphs died after surviving for 9 days	-	-	-
	IV nymph (late)	0.5	30	15	Body shrank and all nymphs died immediately	—	—	—
	V_o nymph	0.5	5	10	Died immediately	—	—	
	V_3 nymph	0.5	5	16	Occurred, wings moderately deformed	Interrupted	50 ± 2	> 85
	V_3 nymph	0.5	10	18	Occurred wings severely deformed	Interrupted	40 ± 2	~ 80
	V_3 nymph	0.5	15	15	9 became adultoids, 6 died	—	—	—
	V_3 nymph	0.5	20	10	All died	—	—	—
	A_0 adult	0.5	10	10	—	Interrupted	45 ± 2	~ 30
	A_0 adult	1.0	10	10	—	All died before mating	—	
	A_3 adult	1.0	20	10	—	All died before mating	—	—

TABLE 1. (Continued.)

Insecticide	Stage	Concentration (%)	Dose (μl)	No. Treated	Effects on Molting/hatching	Mating	Fecundity (No. of eggs)	(%) hatching
Multineem	V_3 nymph	0.5	5	12	Occurred, right forewing very small, no right hind wing, left forewing comparatively large with normal hind wing	Interrupted	60 ± 2	~ 87
	A_0	1	10	10	—	All died before mating	—	—
	A_3	1	20	10	—	All died before mating	—	—
	3 day old eggs from normal bugs	2.5	10	90	Only 8 eggs hatched, rest shrank and died	—	—	—
	3 day old eggs from treated bugs	0.5	5	20	All died	—	—	—

TABLE 1. (Continued.)

Insecticide	Stage	Concentration (%)	Dose (μl)	No. Treated	Effects on			
					Molting/hatching	Mating	Fecundity (No. of eggs)	(%) hatching
Neemazal	III nymph (late)	0.25	5	20	Occurred in 13, abnormal, exuviae attached to posterior body end, hind wing covering abdominal segments incompletely, 7 nymphs died	All died before mating	–	–
	V_3 nymph	0.25	8	20	13 became adultoids, 7 died as nymph	—	—	—
	V_3 nymph	0.5	3	10	Occurred, abnormal, wings severely deformed, delayed for 2 days	—	—	—
	V_3 nymph	0.5	5	15	10 became adultoids, 5 died as nymph	—	—	—
	V_3 nymph	1.0	2	10	Occurred, wings severely deformed	—	—	—
	V_3 nymph	1	20	10	All died as nymphs	—	—	—
	A_0 adult	0.5	10	18	9 died prior to mating	9 mated	30±2	~ 45
	A_0	0.5	20	10	—	All died before mating	—	—
	A_2	1.0	20	10	–	All died before mating	—	—
Acetone treated controls for all experiments separately					Occurred, normal	Prolonged mating	104 ± 3	> 97

TABLE 2. Effects of neem-based insecticides (0.25% conc.) on total haemocytes count in V instar nymphs of *Dysdercus koenigii*

Treatment	Dose μl	THC (No. of cells/mm^3 of haemolymph) at 24 h	48 h	72 h	96 h	120 h
Nimbecidine	5	3188 ± 242	2795 ± 260	3462 ± 160	4690 ± 194	5865 ± 265
Neemazal	5	3005 ± 190	2640 ± 260	3262 ± 192	4365 ± 240	5676 ± 300
Multineem	5	3262 ± 230	2867 ± 150	3569 ± 260	4764 ± 245	5965 ± 360
Acetone treated control	5	6410 ± 385	6775 ± 292	7170 ± 240	7490 ± 368	—

The values represent mean ± SD for 20 nymphs.

TABLE 3. Effects of neem-based insecticides (0.25% conc.) on differential haemocytes count in V instar nymphs of *Dysdercus koenigii*

Haemocyte types	Haemocyte percentage 24 h post treatment: Acetone treated control	Nimbecidine	Neemazal	Multineem
PRs	7.6 ± 0.3	2.4 ± 0.7(69%)	2.0 ± 0.3 (74%)	2.2 ± 0.4 (71%)
PLs	47.4 ± 1.7	35.6 ± 3.1 (25%)	29.9 ± 1.5 (37%)	34.0 ± 2.2 (28%)
GRs	32.7 ± 2.8	24.4 ± 14.7 (25%)	22.2 ± 2.0 (32%)	24.6 ± 1.8 (25%)
ADs	8.3 ± 0.9	19.3 ± 2.1 (132%)	24.6 ± 2.8 (196%)	20.6 ± 1.5 (148%)
OEs	4.0 ± 0.2	18.3 ± 1.2 (357%)	21.3 ± 2.7 (432%)	18.6 ± 2.1 (365%)

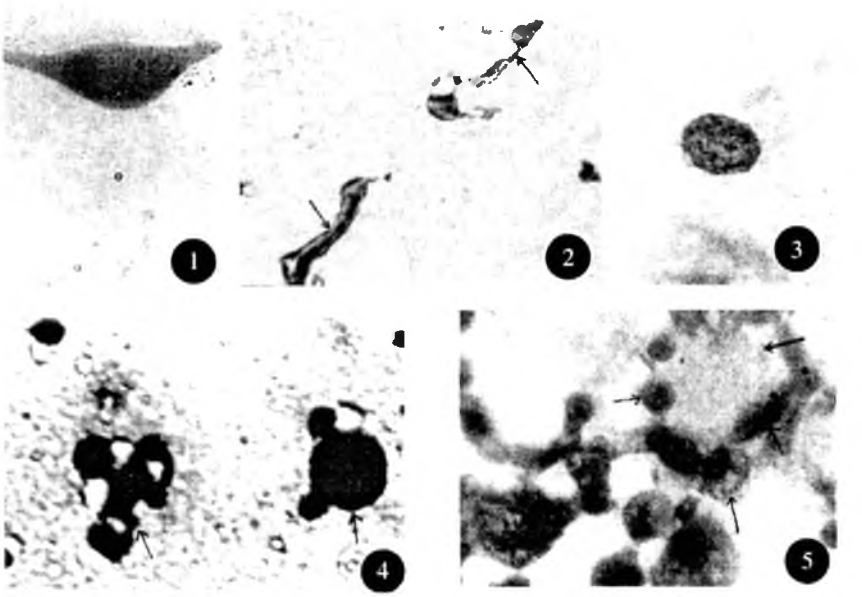
The values represent mean ± SD for 20 nymphs. Figures in parentheses show % increase and % decrease in the number of haemocytes.

producing adultoids respectively, depending upon different concentrations and doses of NBI applied. These adultoids had higher body length (1.32 ± 0.03 cm) in contrast to control 5th instars (1.18 ± 0.02 cm). A few adultoids showed loss of their characteristic nymphal spots on their abdominal tergites; others had 3-segmented tarsi instead of 2 segmented tarsi as in the normal case. Still some of the adultoids showed larger wings but shrunken abdomen.

Table 1 further shows that application of 5–10 μl dose of 0.5% NBI caused interruption in normal (prolonged) mating and finally resulted in reduced fecundity and eggs hatchability too.

Effects on haemocytes count

Application of 5μl of 0.25% of all the three NBI failed to prevent the normally occurring increase in number of haemocytes during the nymphal development excepting a considerable drop in 48 h old treated nymphs; it caused an overall reduction in the haemocytes count in comparison with Acetone treated control (Table 2). The variation in relative percentage of haemocyte types is evident in the treated nymphs after 24 h (Table 3).



FIGURES. 1–5: 1. A spindle shaped Plasmatocyte from control 5th instar nymph (X 1500), 2. Plasmatocytes (arrows) showing structural deformity following 5μl dose of 2.5% multineem on 3 days old 5th instar nymph (X 1000), 3. A spherical Granulocyte from control 5th instar nymph (X 1500), 4. Much deformed Granulocytes (arrows) after treatment with 5 μl dose of 0.5% nimbecidine on 3 days old 5th instar nymph (X 1500), 5. Capsule formation involving Plasmatocytes and Granulocytes (thin arrows) enclosing circular islet (thick arrow) following application of 5 μl dose of 02.5% multineem on 1 day old adult bug (X 1500).

NBI caused maximum reduction in prohaemocytes (PRs) counts (Table 3). Plasmatocytes (PLs) and granulocytes (GRs) also showed reduction, but to a lesser extent. Adipohaemocytes (ADs) and Oenocytoids (OEs) showed much increase in their numbers.

Effects on haemocytes morphology

Treatment with all the NBIs caused deformity in all types of cells. However, PLs and GRs had more pronounced effect (Figs. 1–4) of NBI. The NBI induced aggregation of cells, encapsulation (Fig. 5) and nodule formation. PLs and GRs appear to participate in capsule formation by way of fusing with each other (Fig. 5) showing vacuolization. PLs lost their pseudopodia and consistency thereby becoming almost translucent. GRs were seen with vesicles/vacuolar structures (exocytotic vesicles) on their periphery with a number of cells found entangled. The nuclei of GRs had several finger like projections demonstrating their necrosis. In addition, a few partly broken GRs devoid of plasma membrane and cellular contents were also observed.

DISCUSSION

The neem-based insecticides show varied effects on *D. koenigii* including regional variation with respect to their sensitivity on the insect body. The NBI cause physiological disturbances leading to developmental abnormalities like prolongation of nymphal stage; ecdysial stasis, adultoids and deformed nymphs/adults. All these could be due to disturbance in the endocrine functions of treated insects (Schmutterer, 1990). On the other hand NBI causing failure of egg's hatching could be due to their ovicidal effect. The NBI treatment also caused interruption in mating and loss of fecundity. This is in consonance with the observation of Dorn *et al.* (1987) in *Oncopeltus*. Reduction in mating period and fecundity (egg numbers) could be due to interrupted release of juvenile hormone (JH) from CA as a result of application of NBI. The involvement of JH as reproductive hormone is well documented in *Dysdercus koenigii* (Venugopal and Kumar, 1997). Our finding that NBIs are less effective on 5th instar as compared to adults with regard to eggs hatchability could be due to degradation of NBI during the development of 5th instar to imago. Contrary to this, insecticides might directly act on the processes of egg production, when applied to the adults, thereby causing reduction in eggs hatchability. This is in contrast with observation of earlier workers (Medina *et al.*, 2004; Tanzubil and McCaffery, 1990).

NBI treatment caused drastic reduction in THC as reported for *R. prolixus* (Azambuja *et al.*, 1991) and *S. litura* (Sharma *et al.*, 2003), which could be due to formation of nodules or inhibitory effects of insecticides on endocrine glands.

Neemazal caused much more decline in THC vis-à-vis nimbecidine and multineem application (vide Table 2). It also affects the DHC of PRs, PLs, GRs (vide Table 3) suggesting their maximum contribution in this cell type counts. Further, reduction in counts of PLs and GRs could be due to their involvement in phagocytosis and nodule formation after NBI application (Sharma *et al.*, 2003).

The deformities caused by NBI in haemocytes leading to necrosis and eventually death are known in *Dysdercus koenigii* (Saxena and Tikku, 1990) and *S. litura* (Sharma *et al.*, 2003). Such changes were also reported in *Papilio demoleus* after administering certain physical stresses like starvation, chilling and heating (Pandey *et al.*, 2003). Therefore treatment of NBI could be taken as a chemical stress affecting neurosecretory cells in the brain. However, further studies are needed to pin point the exact mode of action of NBI.

ACKNOWLEDGEMENTS

RKT thanks the University Grants Commission, New Delhi, India for financial assistance. Authors are grateful to the editorial team of the 'Entomon' for valuable suggestions and modifications.

REFERENCES

Azambuja, P. D., Garcia, E. S., Ratcliffe, N. A. and Warthen, J. D. Jr (1991) Immune depression in *Rhodnius prolixus* induced by the growth inhibitor Azadirachtin. *Journal of Insect Physiology* **37**: 771–777.

Dorn, A., Rademacher, H. and Sehn, E. (1987) Effects of Azadirachtin on reproductive organs and fertility in the large milkweed bug. *Oncopeltus fasciatus*. In: *Proceedings, Natural Pesticides from the Neem Tree and Other Tropical Plants*, 3rd International Neem Conference, 10–15 July 1986, Nairobi, Kenya. Schmutterer, H. and Ascher, K. R. S. (Eds). pp. 273–288.

Jones, J. C. (1962) Current concepts concerning insect haemocytes. *American Zoologist* **2**: 209–246.

Medina, P., Budia, F., Estal, P. D. and Vinuela, E. (2004) Influence of Azadirachtin, a Botanical Insecticide, on *Chrysoperla carnea* (Stephens) (Neuroptera) Reproduction: Toxicity and Ultrastructural approach. *Ecotoxicology* **97(1)**: 43–50.

Mordue (Luntz), A. J., Sommonds, M. S. J., Ley, S. V., Blaney, W. M., Modue, W., Nasiruddin, M. and Nisbet, A. J. (1998) Action of Azadirachtin, a plant allelochemical against insects. *Pesticide Science* **54**: 277–284.

Pandey, J. P., Tiwari, R. K. and Chaubey, A. K. (2003) Studies on haemocytes of lemon butterfly, *Papilio demoleus* L (Lepidoptera) under certain stress conditions. *Journal of Animal Morphology and Physiology* **50**: 33–44.

Pandey, J. P. and Tiwari, R. K. (2005) Feeding, brain implantation and 20-hydroxyecdysone treatment reverses the effect of starvation and ventral nerve cord severance on haemocyte counts in larvae of the plain tiger butterfly *Danaus chrysippus* (Lepidoptera: Nymphalidae). *International Journal of Tropical Insect Science* **25(4)**: 295–300.

Saxena, B. P. and Tikku, K. (1990) Effects of plumbagin on haemocytes of *Dysdercus koenigii* F. *Proceedings of Indian Academy of Sciences (Animal Science)* **99**: 119–124.

Schmutterer, H. (1990) Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. *Annual Review of Entomology* **35**: 271–297.

Sharma, P. R., Sharma, O. P. and Saxena, B. P. (2003) Effect of neem gold on haemocytes of the tobacco armyworm, *Sodoptera litura* Fab (Lepidoptera, Noctuidae). *Current Science* **84**: 690–695.

Takeda, N. (1977) Brain hormone carriers haemocytes in the moth, *Monema flavescens*. *Journal of Insect Physiology* **23**: I245–1254.

Tanzubil, P. B. and McCaffery, A. R. (1990) Effect of Azadirachtin on reproduction in the African armyworm (*Spodoptera exempta*). *Entomology Experimental & Applied* **57**: 115–121.

Venugopal, K. J. and Kumar, D. (1997) Hormonal regulation of Vitellogenin synthesis and incorporation in *Dysdercus koenigii*. In: *Advances in Comp. Endocrinology. Proceedings of the XIIIth International Congress of Comp. Endocrinology, Yokohama, Nov. 17-21*, pp. 221–224.

(Received 28 March 2006; accepted 23 November 2006)

ENTOMON 31(4): 277–286 (2006)
Article No. ent.31404

Phylogenetic consideration of the primary setae and pores on the cephalic capsule and head appendages of three species of *Hyphydrus* Illiger larvae (Coleoptera: Dytiscidae: Hydroporinae)

D. Manivannan and J. Issaque Madani

P.G. & Research Department of Zoology, The New College, Chennai - 600014, India

ABSTRACT: Studies on the primary setae and pores of the cephalic capsule and head appendages of three species of Hyphydrini show the homology of 18 setae and 20 pores among *Hyphydrus sumatrae*, *H. flavicans* and *H. renardi*. Generally hyphydrine larvae share 3 setae and 1 pore on the cephalic capsule, 1 seta on the antenna, 11 setae and 3 pores on labium, 1 seta on the maxilla and 3 pores on the mandible. Species differences among the hyphydrine larvae are discussed in the phylogenetic perspective. The observation indicates a monophyletic origin of Hyphydrini as strongly supported by plesiomorphies and synapomorphies as seen in H. sumatrae, H. flavicans and H. renardi.

KEYWORDS: *Hyphydrus sumatrae*, *H. flavicans*, *H. renardi*, plesiomorphies, synapomorphies

INTRODUCTION

Chaetotaxal analysis of the larval cephalic capsule and head appendages have been previously attempted in different groups of Dytiscidae. DeMarzo gave an account of chaetotaxal studies on a few species of colymbetines (1973, 1974a, 1974b, 1976a) and some laccophilines (1976b) and hydroporines (1977). Wolf and Roughly (1985) has given an account of mouth parts of *Matus ovatus ovatus*.

Recent studies have demonstrated the taxonomic and phylogenetic value of both chaetotaxal and porotaxal analyses in studying larval Hydroporinae (Nilsson, 1986, 1987a,b,c, 1988, 1989; Nilsson and Carr, 1989; Alarie and Harper, 1990; Alarie *et al.*, 1990), last abdominal segment and urogomphi (Alarie and Harper, 1990) have suggested that primary pores and setae observed on these structures could be similar throughout the subfamily Hydroporinae. Alarie (1991) studied the pores and setae on first instar larvae of 30 Nearctic species of Hydroporinae.

In a phylogenetic perspective it is useful to study for new characters in order to increase knowledge about the group under study to improve hypotheses deduced for phylogenetic reconstruction. This paper represents the effort to record and number the primary sensilla of three species namely *Hyphydrus sumatrae, H. flavicans* and *H. renardi* from Oriental region. The objectives of this paper are: (i) to examine both the chaetotaxy and porotaxy of the cephalic capsule and head appendages of first instar larvae of Hydroporinae especially belonging to Hyphydrini (ii) to propose the ancestral pattern of primary setae and pores for these species and to interpret the synapomorphic and plesiomorphic characters.

MATERIALS AND METHODS

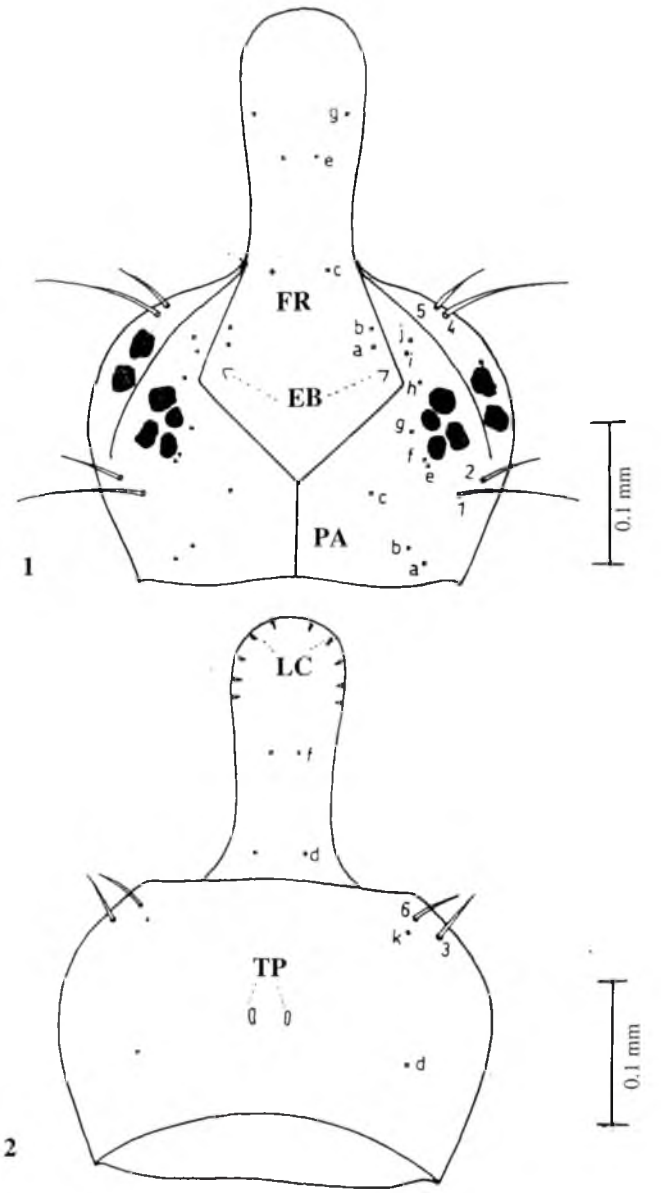
The notation of the primary setae and pores is based on the study of first instar larvae of three species compared to the outgroups as mentioned by Alarie (1991). The eggs were collected from the adults maintained in the laboratory at room temperature. The larvae were reared ex-ovo using the techniques described by Alarie *et al.* (1989). Cephalic capsule and head appendages were dehydrated in alcohol series, mounted in Canada balsam, and examined under a compound microscope. The terminology used is that of Bousquet and Goulet (1984); Wolf and Roughly (1985) and Alarie (1991). The slides are deposited with author collection in the School of Entomology, Department of Zoology, The New College, Chennai, India.

RESULTS

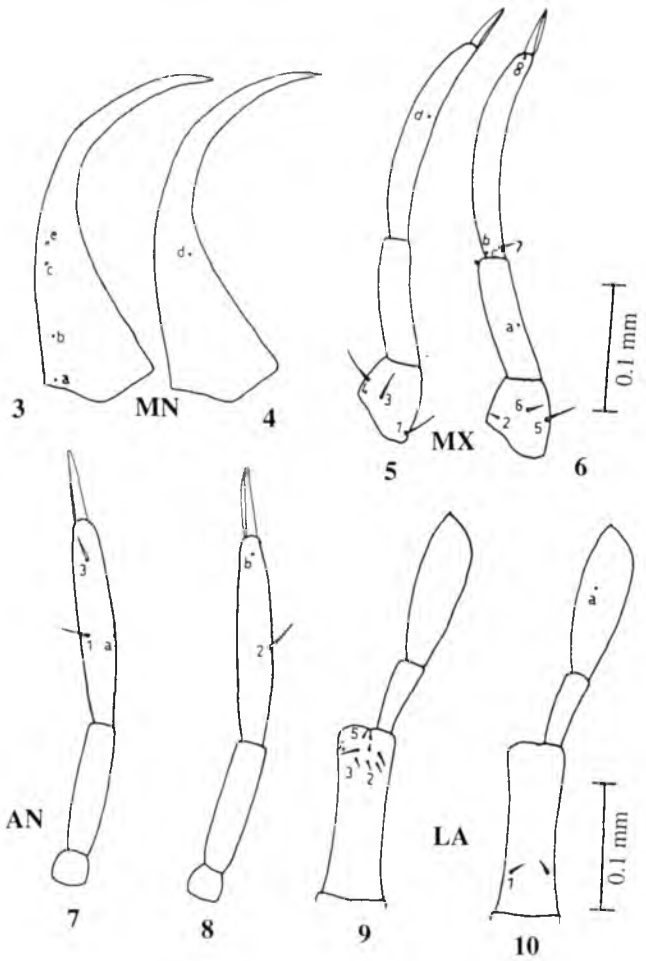
Morphological hypothesis of homology of primary setae and pores on cephalic capsule and head appendages is based mainly on the criterion on similarity in position. In the cephalic capsule, frontoclypeus contains one pore which is homologous in the three species *H. sumatrae* (FRe), *H. flavicans* (FRd) and *H. renardi* (FRa) whereas in parietale three setae and five pores are present in same position on the dorsal aspect PA2, PA4, PA5, PAa, PAb, Pag, PAi an Paj in *H. sumatrae*, in *H. flavicans* PA2, PA7, PA6, PAa, PAd, PAl, PAm and PAi and PA1, PA4, PA3, PAa, Pab, PAd, PAf and PAc in *H. renardi*. In ventral aspect except *H. renardi* the other species have two setae in parietale PA6, PA3 equal to PA5, PA4 common in *H. flavicans* and *H. sumatrae*

The primary sensilla on head appendages consists of fourteen setae and eight pores that are homologous in position in the three species observed. Antenna having only one seta sharing the same position except in *H. renardi*, in which no pores are in homologous position. There are eleven setae and three pores on labium, the setae LA3, LA2, LA4, LA6, LA7, LA5, LA10, LA11, LA1, LA9 and LA8 of *H. flavicans* are equal to LA3, LA2, LA4, LA7, LA6, LA5, LA13, LA12, LA11, LA10 of *H. renardi* and LA2, LA3, LA4, LA5, LA1 of *H. sumatrae* similar in position of LA4, LA6, LA7, LA5, LA1 of above two species and also in *H. flavicans* LAb, LAd, LAg, sharing the same position of LAb, LAc and LAd of *H. renardi*. In *H. sumatrae* these pores are lacking.

The seta MX1 of *H. flavicans* shares the common position of MX2 of *H. sumatrae*

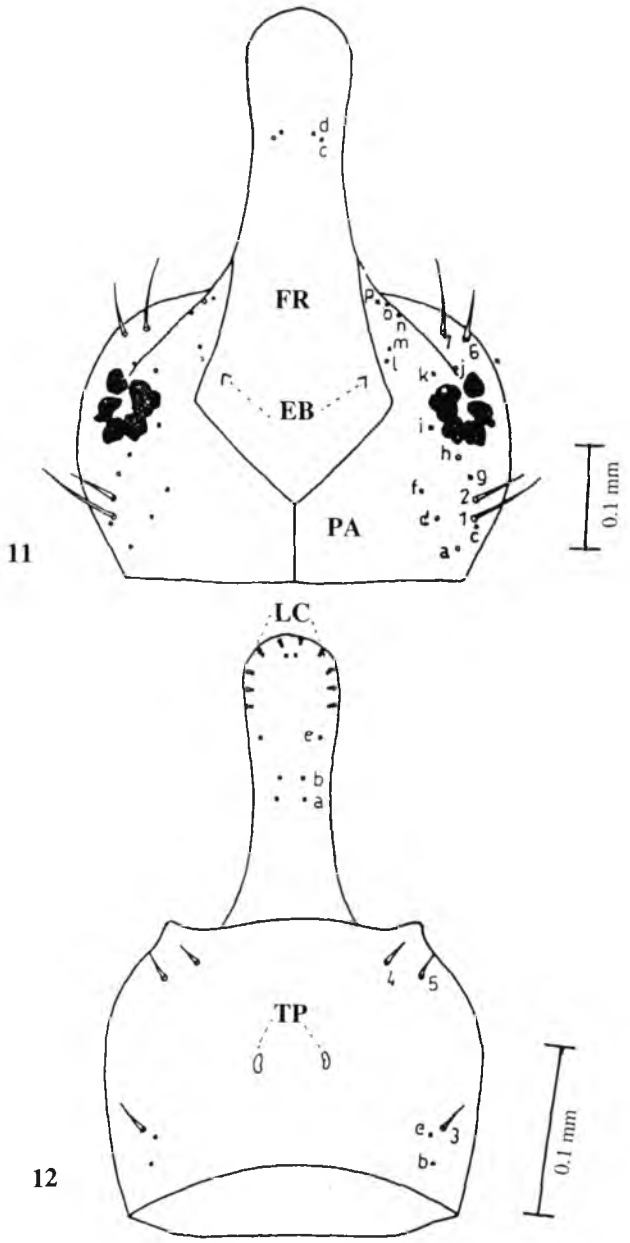


FIGURES 1–2: *Hyphydrus sumatrae*, first instar larva: 1, Cephalic capsule, dorsal aspect; 2, Cephalic capsule, ventral aspect; FR, frontoclypeus; LC, lamellae clypeales; PA, parietale; TP, tentorial pits. Numbers and lowercase letters refer to primary setae and pores. Scale bar: 0.1 mm.

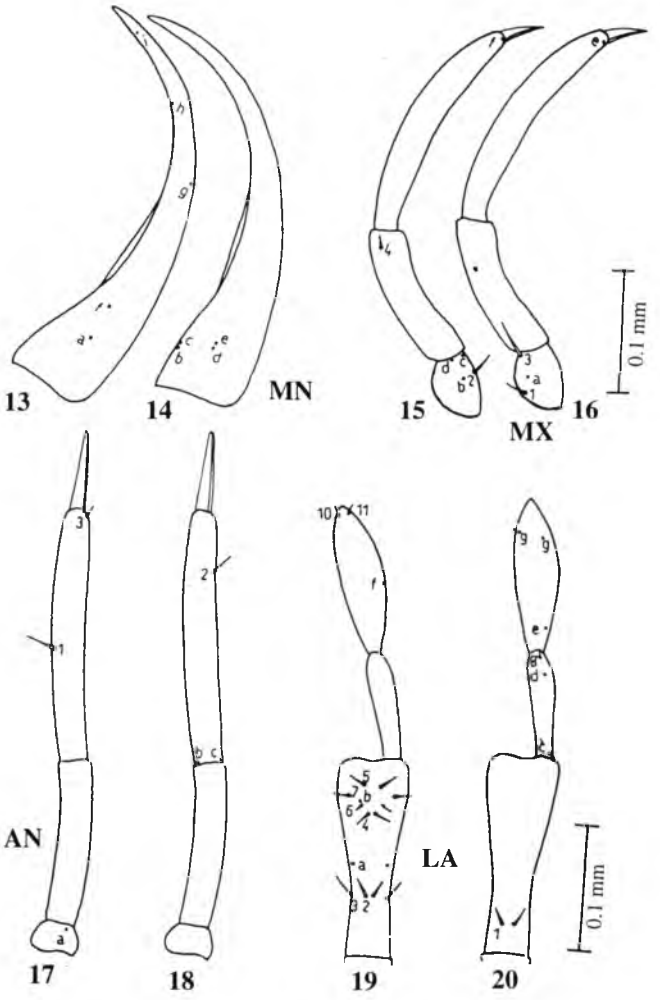


FIGURES 3–10: *Hyphydrus sumatrae*, first instar larva: 3, mandible, dorsal aspect; 4, mandible, ventral aspect; 5, maxilla, dorsal aspect; 6, maxilla, ventral aspect; 7, antenna, dorsal aspect, 8, antenna, ventral aspect, 9, labium, dorsal aspect; 10, labium, ventral aspect; MN, mandible; MX, maxilla; AN, antenna; LA, labium. Numbers and lowercase letters refer to primary setae and pores. Scale bar: 0.1 mm.

and seta of MX5 of *H. renardi* is homologized to MX3 of *H. flavicans,* while it is lacking in *H. sumatrae*. The three pores MXf, MXe, Mxa are also absent in *H. sumatrae*. The mandibular pores MNd, MNe of *H. flavicans* and MNc, MNf are similar in position to those of *H. renardi* on ventral aspect. Dorsally MNm of *H. renardi* is corresponding position to that of *H. sumatrae*, but it is lacking in *H. flavicans*.



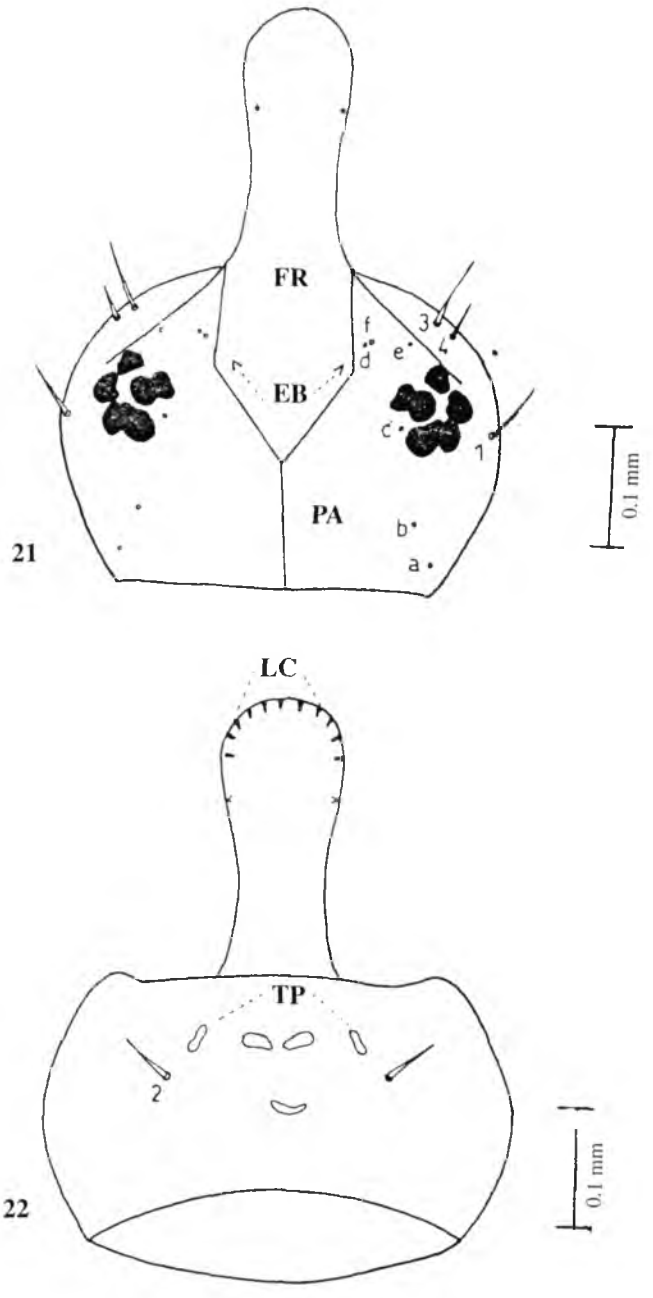
FIGURES 11–12: *Hyphydrus flavicans*, first instar larva: 11, Cephalic capsule, dorsal aspect; 12, Cephalic capsule, ventral aspect; FR, frontoclypeus; LC, lamellae clypeales; PA, parietale; TP, tentorial pits. Numbers and lowercase letters refer to primary setae and pores. Scale bar: 0.1 mm.



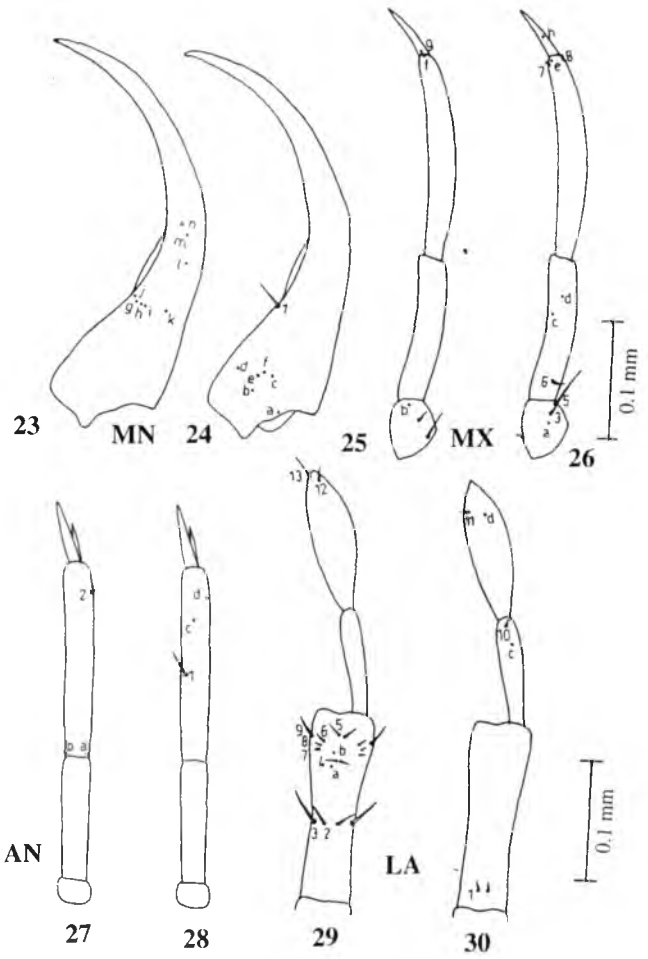
FIGURES 13–20: *Hyphydrus flavicans*, first instar larva: 13, mandible, dorsal aspect; 14, mandible, ventral aspect; 15, maxilla, dorsal aspect; 16, maxilla, ventral aspect; 17, antenna, dorsal aspect, 18, antenna, ventral aspect, 19, labium, dorsal aspect; 20, labium, ventral aspect; MN, mandible; MX, maxilla; AN, antenna; LA, labium. Numbers and lowercase letters refer to primary setae and pores. Scale bar: 0.1 mm.

DISCUSSION

Alarie (1991) has reported the monophyletic origin of Hydroporini, Bidessini and Hyphydrini due to the absence of two pores PAd and PAe, a character which they share. The same pores are also lacking in *Pachydrus* of Hyphydrini (Alarie *et al.*, 1997). Moreover, except for *Hygrotus*, both pores PAd and PAe are consistently lacking



FIGURES 21–22: *Hyphydrus renardi*, first instar larva: 21, Cephalic capsule, dorsal aspect; 22, Cephalic capsule, ventral aspect; FR, frontoclypeus; LC, lamellae clypeales; PA, parietale; TP, tentorial pits. Numbers and lowercase letters refer to primary setae and pores. Scale bar: 0.1 mm.



FIGURES 23–30: *Hyphydrus renardi*, first instar larva: 23, mandible, dorsal aspect; 24, mandible, ventral aspect; 25, maxilla, dorsal aspect; 26, maxilla, ventral aspect; 27, antenna, dorsal aspect, 28, antenna, ventral aspect, 29, labium, dorsal aspect; 30, labium, ventral aspect; MN, mandible; MX, maxilla; AN, antenna; LA, labium. Numbers and lowercase letters refer to primary setae and pores. Scale bar: 0.1 mm.

within the subfamily Hydroporinae (Alarie, 1991). But PAe is present in *H. renardi* in the position of PAd, in *Hygrotus*. In the two other species *H. flavicans* and *H. renardi* it is lacking.

Monophyletic origin of Hyphydrini is strongly supported by the following synapomorphies, as reported by Alarie *et al.* (1997): absence of PAj on epicranial plate on the ventral midline; absence of pore FRb, medioventral position of seta FR6; presence of seta AN1 except AN2 in *H. sumatrae* and AN1 on dorsal aspect of *H. renardi*; ab-

sence of pore ANf; presence of four setae MX2, MX3, MX6 and MX9 of Hyphydrini (Alarie *et al.*, 1997) are observed in the three species of *Hyphydrus* which have been studied. The setae MX4, MX3, MX2 and MX8 of *H. sumatrae*, the two setae MX3 and MX4 occur in *H. flavicans* and MX3 except other setae such as MX2, MX4 and MX8 occur in *H. renardi*. Eight labial setae LA4, LA6, LA7, LA5, LA3, LA11, LA9 and LA1 of the three species of *Hyphydrus* are similar in position as in the rest of Hyphydrini. The three setae LA8, LA11 and LA12 are absent in *H. sumatrae*. Two pores on mandible such as MNa and MNe of *H. flavicans* are corresponding to MNb and MNd of other Hyphydrini. The pore MNd is absent in *H. renardi*, whereas *H. sumatrae* can be distinguished by the absence of both MNb and MNd.

The monophyletic origin of Hyphydrini is supported also by the plesiomorphies. Alarie (1991) has reported the presence of the three setae and two pores on parietale (PA21, PA11 and PA12) of Hyphydrini. The three species of *Hyphydrus* in the present study have been observed to have the setae PA4, PA6, PA3 in *H. sumatrae*, PA6, PA5, PA4 in *H. flavicans*, while *H. renardi* has only PA3 as equal to PA21 of Hydrophorinae (Alarie, 1991). The setae PA10, PA11 and PA12, observed in Carabidae (Bousquet and Goulet, 1984), two pores PAc and PAe of Hyphydrini, and pores PAc and PAd of Carabidae are pleisiomorphic. In *H. flavicans* these pores are absent. The pore PAc is present in Hydrophorinae. There is one pore FRb in *H. sumatrae* in the same position as *Laccornis latens* (Alarie, 1991) and comparable to FRd in Carabidae, as reported by Bousquet and Goulet (1984). These setae and pores deserve to be considered as plesiomorphic. These observations indicate a monophyletic origin of Hyphydrini including *H. sumatrae*, *H. renardi* and *H. flavicans*.

ACKNOWLEDGEMENT

The authors are thankful to Mr A. Kadar Basha, Principal, The New College, Chennai-14 and Dr M. Mohamed Ismail, Head of the Department of Zoology, The New College, for their encouragement and providing necessary facility. Authors immensely thank Dr. A. Jawahar Ali, Senior Lecturer in Zoology, The New College, for going through the manuscript and for suggestions. The authors express their gratitude to University Grants Commission for funding.

REFERENCES

Alarie, Y., Harper, P. P. and Maire, A. (1989) Rearing Dytiscid beetles (Coleoptera, Dytiscidae). *Ent. Basil.* **13**: 147–149.

Alarie, Y. and Harper, P. P. (1990) Primary setae and pores on the last abdominal segment and the urogomphi of larval Hydroporinae (Coleoptera: Adephaga: Dytiscidae), with notes on other dytiscid larvae. *Can. J. Zool.* **68**: 368–374.

Alarie, Y., Harper, P. P. and Maire, A. (1990) Primary setae and pores on legs of larvae of Nearctic Hydroporinae (Coleoptera: Dytiscidae). *Quaest. Ent.* **26**: 199–210.

Alarie, Y. (1991) Primary setae and pores on the cephalic capsule and head appendages of larval Hydroporinae (Coleoptera: Dytiscidae: Hydroporinae). *Can. J. Zool.* **69**: 2255–2265.

Alarie, Y., Vang, L. J., Nilsson, A. N. and Spangler, P. J. (1997) Larval morphology of four genera of the tribe Hyphydrini Sharp (Coleoptera: Dytiscidae: Hydroporinae) with an analysis of their phylogenetic relationship. *Ann. Ent. Soc. Am.* **90(6)**: 709–735.

Bousquet, Y. and Goulet, H. (1984) Notation of primary setae and pores on larvae of Carabidae (Coleoptera: Adephaga). *Can. J. Zool.* **62**: 573–588.

De Marzo, L. (1973) Studies on the larvae of Coleoptera Dytiscidae. I. Morphological notes on the mature larvae of six species of *Agabus* Leach. *Entomologica* **9**: 47–83.

De Marzo, L. (1974a) Studies on the larvae of Coleoptera Dytiscidae. II. Morphology of the three larval stages of *Melanodytes pustulatus* Rossi. *Entomologica* **10**: 57–80.

De Marzo, L. (1974b) Studies on the larvae of Coleoptera Dytiscidae. III. Morphological notes on the I and II larval instars of six species of *Agabus* Leach. *Entomologica* **10**: 81–108.

De Marzo, L. (1976a) Studies on the larvae of Coleoptera Dytiscidae. IV. Morphology of three larval instars of *Copelatus haemorroidalis F.*. *Entomologica* **12**: 89–101.

De Marzo, L. (1976b) Studies on the larvae of Coleoptera Dytiscidae. V. Morphological notes on the larvae of three species of the genus *Laccophilus* Leach. *Entomologica* **12**: 107–129.

De Marzo, L. (1977) Notes on Dytiscidae larvae VIII. Morphology of the three larval instars of *Oreodytes rivallis* Gyll and *Hyphydrus auberi* Ganglb and some remarks on the behaviour of the exoskeletal character in the larval forms of the subfamily Hydroporinae. *Entomologica* **13**: 85–119.

Nilsson, A. N. (1986) Larval morphology and phenology of four Fennoscandian species of *Hydroporus* Clairville (Coleoptera: Dytiscidae), with a preliminary key to the known larvae. *Aquatic Insects* **8**: 141–153.

Nilsson, A.N. (1987a) Larval morphology of Fennoscandian *Oreodytes* Seidlitz (Coleoptera: Dytiscidae), with notes on hydroporineleg chaetotaxy and taxonomy. *Entomol. Tidskr* **108**: 99–108.

Nilsson, A. N. (1987b) The larva of *Rhantus fennicus* (Coleoptera: Dytiscidae), with a key to the Fennoscandian species of *Rhantus*. *Note. Entomo.* **67**: 33–41.

Nilsson, A. N. (1987c) A key to the first instar larvae of Fennoscandian *Agabus* Leach (Coleoptera: Dytiscidae). *Fauna Nor. Ser. B* **34**: 131–137.

Nilsson, A. N. (1988) A review of primary setae and pores on legs of larval Dytiscidae (Coleoptera). *Can. J. Zoology.* **66**: 2283–2294.

Nilsson, A. N. (1989) Larvae of Northern European *Hydroporus* (Coleoptera: Dytiscidae). *Syst. Entomol.* **14**: 99–115.

Nilsson, A. N. and Carr, R. (1989) The third instar larvae of *Hydroporus fuscipennis, H. gyllenhalii* and *H. lapponem* (Coleoptera: Dytiscidae). *Entomol. Tidskr* **110**: 165–170.

Wolf, G. W. and Roughly, R. E. (1985) Description of the pupa and mature larva of *Matus ovatus ovatus* (Coleoptera: Dytiscidae) with a chaetotaxal analysis emphasizing mouth parts, legs and urogomphus. *Proc. Acad. Nat. Sci. Phila.* **137**: 61–79.

(Received 16 December 2005; accepted 7 August 2006)

ENTOMON 31(4): 287–292 (2006)
Article No. ent.31405

A new species of green lynx spider of the Genus *Peucetia* Thorell (Araneae: Oxyopidae) from Tamil Nadu, India

S. Murugesan[1], M. J. Mathew[2], A. V. Sudhikumar[2], E. Sunish[2], C. R. Biju[3] and P. A. Sebastian[2]

[1]*Division of Forest Protection, Institute of Forest Genetics and Tree Breeding, R. S. Puram, Coimbatore 641002, Tamil Nadu, India*
[2]*Division of Arachnology, Department of Zoology, Sacred Heart College, Thevara, Cochin, Kerala 682013, India*
[3]*Department of Agricultural Entomology, Biological Control of Crop Pests and Weeds, College of Horticulture, Kerala Agricultural University, Vellanikkara 680654, Thrissur, Kerala, India*

ABSTRACT: A new species *Peucetia ananthakrishnani* sp. nov. of the family Oxyopidae is described from Tamil Nadu, India.

KEYWORDS: *Peucetia ananthakrishnani*, Lynx spider, Oxyopidae, new species, Tamil Nadu

INTRODUCTION

Members of the genus *Peucetia* Thorell, 1869 are called green lynx spiders. This genus is distributed in predominantly Ethiopian (25 species) and Neotropical (22 species) regions (Platnick, 2006). Several species, however, were reported from the Palaearctic, Oriental and Australian regions. A total of 17 *Peucetia* species are so far known from India including a recently described new species from West Bengal (Saha and Raychaudhuri, 2004; Siliwal *et al.*, 2005). Of late, a few individuals of a *Peucetia* species were collected from the Institute of Forest Genetics and Tree Breeding (IFGTB) campus of Coimbatore, Tamil Nadu, India. The taxa is considered new and hence described and illustrated. The types are deposited in the Division of Arachnology, Dept. of Zoology, Sacred Heart College, Thevara, Cochin, Kerala.

MATERIALS AND METHODS

The second author collected the specimens using hand picking method during a biodiversity study of IFGTB campus in April, 2005. The collected spiders were preserved in

75% alcohol in the field and then studied under a stereo-zoom microscope (Olympus–SZ 112) and the figures were drawn using a camera lucida (Leica 10446193) attached with the microscope. Dissected epigyne were digested in 10% KOH for approximately 24 hrs at room temperature to digest the soft tissue, rinsed in distilled water, stained in ethanol-chlorazol black solution and transferred to 75 percent ethanol for examination (Griswold, 1991). All the measurements are in millimetres, made with an eyepiece graticule. Abbreviation used are as follows: AME–Anterior median eyes, ALE–Anterior lateral eyes, PME–Posterior median eyes, PLE–Posterior lateral eyes.

RESULTS

***Peucetia ananthakrishnani* sp. nov.**

Figs. 1–8.

Female

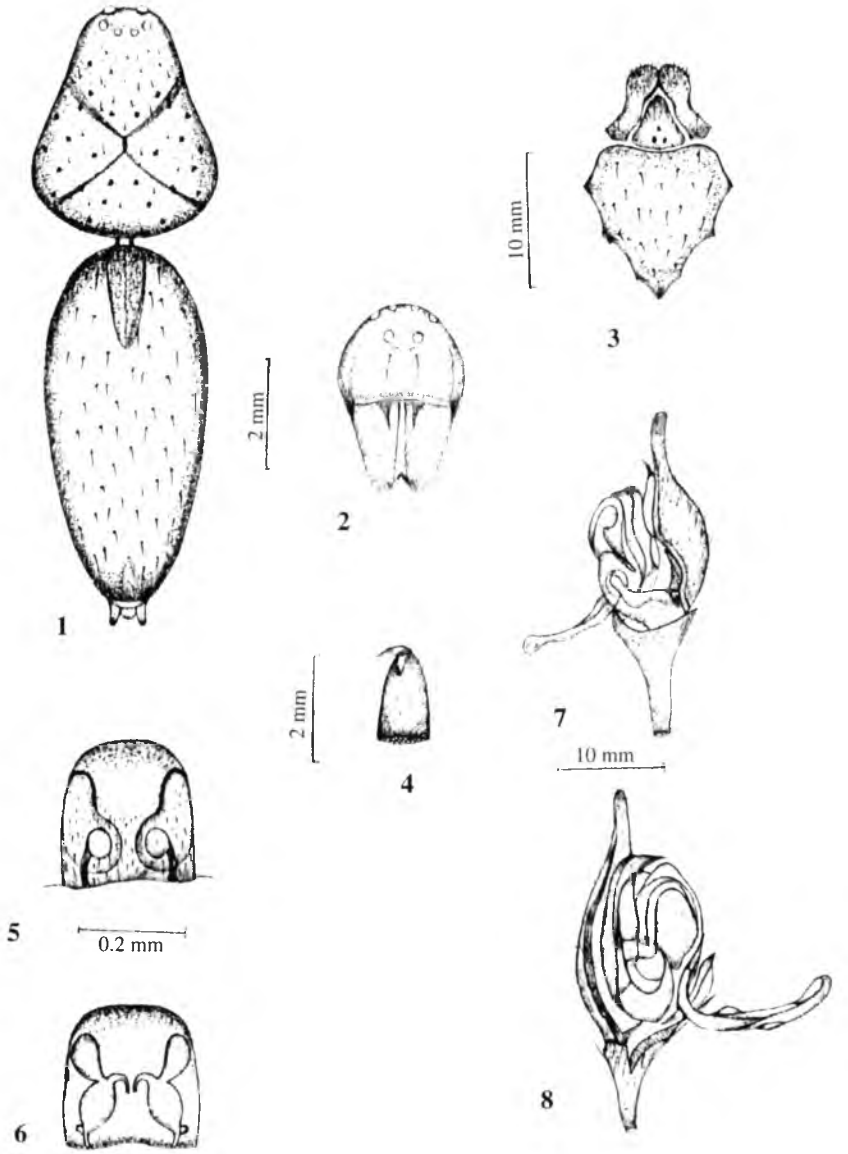
Total length: 10.66 mm

Cephalothorax

Cephalothorax 4.48 mm long, 4.12 mm high and 4.24 mm wide. Light yellow in colour with numerous dark brown spots. Cephalic region lighter than thoracic region. Ocular region orange with grey mat of hairs as in Fig. 1. Anterior lateral eyes surrounded by black rings. Two black lines extend from the AME up to the tip of clypeus as in Fig. 2. A pair of black lines at the corners of clypeus. Cephalothorax with X shaped markings radiating from the long brown fovea. Eye diameter (mm): AME = 0.22, ALE = 0.50, PME = 0.36, PLE = 0.44. Eye separation (mm): AME–AME = 0.28, AME–ALE = 0.32, PME–PME = 0.64, PME–PLE = 0.56, ALE–PLE = 0.54. Clypeus highly raised, 7.5 times AME diameter. Sternum (Fig. 3) light green, heart shaped, with many erect dark hairs and spots, slightly wider than long, anterior margin slightly concave, posterior end tapered. Labium yellowish, longer than wide, reaching more than half the length of the similarly coloured slender maxillae. Apices of maxillae light brown, distally converging and outer lateral midhalf concave. Chelicerae light yellow except the short brown fang with a broad base, retromargin toothless and promargin with a small tooth and a dense mat of yellow brown hairs (Fig. 4). Chelicerae with two longitudinal lateral black lines and a few black spots. Legs light green, long, spinous, and slender with black spots on the base of spines and setae and longitudinal orange bands on the ventral side of coxae and femora of first two legs. Tarsi three clawed, each superior claw in leg I with 4 teeth. Length of leg segments are as in table 1. Leg formula 1243. Pedipalp single clawed with five teeth.

Abdomen

Abdomen 6.18 mm long, 4.51 mm wide. Light green in colour with yellowish tip, nearly elliptical, wide at posterior half from middle, uniformly clothed with black hairs



FIGURES 1-8: *Peucetia ananthakrishnani* sp. nov. 1. Female dorsal view; 2. Frontal view; 3. Sternum with Labium and Maxillae; 4. Chelicerae – lateral view; 5. Epigyne; 6. Internal genitalia; 7. Pedipalp – lateral view; 8. Pedipalp – ventral view.

TABLE 1. Length (mm) of leg segments of the spider *Peucetia ananthakrishnani* sp. nov.

Leg	I		II		III		IV	
	♀	♂	♀	♂	♀	♂	♀	♂
Femur	7.88	(6.12)	6.56	(6.04)	5.54	(4.96)	6.14	(5.88)
Patella	1.74	(1.36)	1.52	(1.26)	1.26	(1.14)	1.52	(1.24)
Tibia	8.88	(6.76)	6.54	(6.02)	4.56	(4.24)	5.22	(4.86)
Metatarsus	9.26	(7.12)	6.84	(5.86)	4.98	(4.72)	6.24	(5.36)
Tarsus	5.22	(3.74)	4.48	(2.24)	2.12	(1.96)	2.24	(2.02)
Total	32.98	(25.10)	25.94	(21.42)	18.46	(17.02)	21.36	(19.36)

and provided with a lenticular milky white mark on the anterior and posterior dorsal tips as in Fig. 1. Venter dark green except yellowish green book lungs, provided with a median broad band from the epigastric furrow to the base of spinnerets. Epigynal region light yellow with a recurved anterior epigynal margin and a tooth like process, each at the anterolateral epigynal boarder, posterior epigynal margin notched medially and located anterior to the epigastric furrow. Yellowish spinnerets close together, anterior pair only slightly longer than the smaller and darker posterior pair. Epigyne and internal genitalia as in Figs. 5 and 6.

Male

Total length: 8.96 mm

Cephalothorax

Cephalothorax 3.82 mm long, 3.24 mm high and 3.32 mm wide. Cephalic region lighter than thoracic region. Ocular quad orange with white hairs. Eye diameter (mm): AME = 0.22, ALE = 0.48, PME = 0.28, PLE = 0.42. Eye separation (mm): AME–AME = 0.20, AME–ALE = 0.12, PME–PME = 0.54, PME–PLE = 0.56, ALE–PLE = 0.52. Clypeus strongly raised, 8 times AME diameter. Cephalothorax with X shaped marking as in female. Sternum light green with black spots. Maxillae brown at base, slightly longer than wide. Labium yellowish brown, longer than wide, apex concave, and reaches a little above midlength of slender, yellow maxillae with moderately converging apices. Apices of maxillae light brown and moderately rounded. Chelicerae yellowish brown, frontally triangular with three setae in a longitudinal row. Promarginal apex with a protrusion lined with a dense mat of hairs, and inner sub base with a blunt transparent tooth. Legs as in female except femora I–IV with numerous black spots. Femora of first three legs with longitudinal orange lines ventrally. Leg formula 1243. Pedipalp longer than femora I. Femur longer than tarsus, bears a prolateral spine distally and 3 dorsal spines. Tibiae with one long prolateral and one retrolateral spine each on basal one third, apex ringed with 6 long spines. Paracymbium sickle shaped, curved at apex projected towards tegulum. Tegular apophysis bears a long spoon shaped process provided with a rounded tooth

or swelling in the middle. Embolus short and thin, arising from basolateral of tegulum and terminating in the robustly sickle shaped conductor anterior to tegulum. Cymbium with a thin blade like outgrowth basally near paracymbium, slender tip with 3 hooked spines. Lateral and ventral views of pedipalp as in Figs. 7 and 8.

Abdomen

Abdomen 5.14 mm long, 2.86 mm wide, 2.24 mm high, widest medially. Dark green in colour, dorsum spotted with orange and with a pair of white lines, entire dorsum clothed with erect yellow brown setae. Presence of milky white bands as in female. Venter with a yellow white median longitudinal band with orange spots. Apices of light brown spinnerets distinctly converging towards each other.

Holotype, ♀

India: Coimbatore, Tamil Nadu; 24, iv, 2005. Collector: Mathew M.J. Deposited in the Division of Arachnology, Dept. of Zoology, Sacred Heart College, Thevara, Cochin, Kerala, India.

Paratypes, 4♀

Same data as holotype. Deposited in the Division of Arachnology, Dept. of Zoology, Sacred Heart College, Thevara, Cochin, Kerala, India.

Allotypes, 2♂

Same data as holotype. Deposited in the Division of Arachnology, Dept. of Zoology, Sacred Heart College, Thevara, Cochin, Kerala, India.

Etymology

The species name is in honour of Dr. T.N. Ananthakrishnan, distinguished entomologist and zoologist, who is the teacher of the first author.

Distribution

Coimbatore, Tamil Nadu, India.

Remarks

This species resembles *P. pawani* Gajbe but differs from it as follows: (1) Carapace provided with X shaped bands. (2) Abdomen dorsally provided with a lenticular powdery white mark. (3) Abdomen ventrally provided with a median broad white band. (4) Epigyne, internal genitalia and pedipalp also structurally different.

Natural history

This spider is found on the ventral side of green leaves of shrubs. Female hangs upside down from the whitish rounded disc shaped cocoon having a diameter of 1.5 to 2.5 cm. Both males and females were collected from the leaves of *Sida* sp. (Collector: Mathew. M.J on 24 April 2005). This spider is characterized by long legs armed with erect spines. It is an agile hunter with keen eyesight. During daytime, it can be found leaping and running on low shrubs in pursuit of preys, which include insects and spiders. The specimens are deposited in the Division of Arachnology, Department of Zoology, Sacred Heart College, Kochi-13.

ACKNOWLEDGEMENTS

We are grateful to the Director, Institute of Forest Genetics and Tree Breeding, for permitting the study. We are also thankful to Rev. Fr. A.J. Saviance, Principal, Sacred Heart College, Thevara, Cochin for providing lab facilities.

REFERENCES

Griswold, C. E. (1991) A revision and phylogenetic analysis of the African spider genus *Machadonia* Lehtinen (Araneae: Lycosoidea). *Entomology Scandinavia* **22(1)**: 305–351.

Platnick, N. I. (2006) The world spider catalog, version 6.5. American Museum of Natural History, online at `http://research.amnh.org/entomology/spiders/catalog/index.html`.

Saha, S. and Raychaudhuri, D. (2004) A new species of spider of the genus *Peucetia* Thorell (Oxyopidae: Araneae) from Digha, Midnapore, West Bengal, India. *Journal of the Bombay Natural History Society* **101(2)**: 288–290.

Siliwal, M., Molur, S. and Biswas, B. K. (2005) Indian Spiders (Arachnida: Araneae): Updated checklist 2005. *Zoos' Print* **20(10)**: 1999–2049.

(Received 29 March 2006; accepted 4 November 2006)

ENTOMON **31(4)**: 293–305 (2006)
Article No. ent.31406

A taxonomic review of *Tetrastichus* Haliday (Hymenoptera: Eulophidae) from Borneo

T. C. Narendran

Systematic Entomology Laboratory, Department of Zoology, University of Calicut, Kerala, 673635, India

ABSTRACT: Three new species viz. *Tetrastichus tanus* Narendran sp. nov., *Tetrastichus baricatus* Narendran sp. nov. and *Tetrastichus wakicus* Narendran sp. nov. are described. The genus *Tetrastichus* Haliday is redefined and comments on four known species are given. A new name for *Neotetrastichus* Narendran is provided. A key to the Bornean species is also given.

KEYWORDS: Review, *Tetrastichus*, new species, Borneo

INTRODUCTION

Borneo islands include the Indonesian Kalimantan and the Malaysian Sarawak and Sabah. Borneo has a very unique forest ecosystem sustaining very interesting parasitic Hymenoptera (Narendran, 2005a,b; Narendran *et al.*, 2004, 2006). However, very little is known of the genus *Tetrastichus* Haliday from this island. So far only five species of *Tetrastichus* viz. *Tetrastichus vadanatus* Narendran, *T. abatus* Narendran, *T. bellus* Narendran, *T. howardi* (Olliff) and*T. schoenobius* Ferriere are known from Borneo. In this paper, three new species of *Tetrastichus* are described and additional information on and a key to the species of the genus from Borneo are given. These new species do neither fit in the key of Graham (1991) nor in any Oriental species listed by Noyes (2006).

Genus *Tetrastichus* Haliday

Tetrastichus Haliday, 1844: 297–298. Type species: *Cirrospilus attalus* Walker [*Eulophus miser* Nees] monotypy.

[See Graham, 1991 for complete list of synonyms]

Diagnosis

Propodeum with a characteristic inverted 'Y' shaped carina (formed by the paraspiracular carina and an additional carina running posteromedially from paraspiracular ca-

rina); submedian areas of propodeum usually well reticulate; outer side of hind coxa in most species with raised reticulations or rugosity; SMV in most species with one dorsal seta (rarely with 2–4 dorsal setae in some species). Body black or brown, often with slight or strong metallic refringence; usually not light coloured.

Host

The world hosts includes egg, larval or pupal stages of various species of Lepidoptera, Coleoptera, Hymenoptera, rarely Odonata and Ootheca of Blattaria. (Boucek, 1988; Graham, 1991; LaSalle, 1994).

Distribution

All continents.

KEY TO SPECIES OF *TETRASTICHUS* OF BORNEO (BASED ON FEMALES)

1. Body completely immaculate yellow or whitish yellow; lower clypeal margin entire; mesoscutum with single adnotaular seta on each side; antenna with one anellus ..... *T. bellus* Narendran
– Body differently coloured; lower clypeal margin bilobed or at least slightly sinuate; mesoscutum with more than one adnotaular seta on each side; antenna with 1–2 anelli 2
2. Mandibles unusually large, falcate (Fig. 8) with a tubercle like tooth on either mandible; maxillary palp relatively long; scape exceeding vertex; epipygium a little longer than 2× length of sixth tergite ..... *T. vadanatus* Narendran
– Mandibles not unusually large, maxillary palp, scape and epipygium different from above 3
3. SMV with 2 dorsal setae 4
– SMV with 1 dorsal seta 5
4. Pronotum with spiracle jetting out on either side; clava (excluding spicula) distinctly longer than F2+F3, a little over 3× as long as wide, with an apical spicula and a relatively large (longer than spicula) seta at its apex; F1 subequal to F2; mesoscutum with 4 adnotaular setae on either side; gaster obtuse apically, 0.76× as wide as long; black without metallic refringence; hind coxa black, fading to yellow apically ..... *T. abatus* Narendran
– Pronotum with spiracle not as above; clava as long as F2+F3, 2.33× as long as wide, without apical long seta as above; F1 distinctly longer than F2; mesoscutum with 3 adnotaular setae on either side; gaster ovate apically, 0.60× as wide as long; black or bluish black; hind coxa yellow with pale brownish tinge ..... *T. howardi* (Olliff)
5. Clava as long as F2+F3; body shining green with some bluish reflections; legs yellow with base of fore coxa and greater part of hind coxa greenish; gaster distinctly longer than metasoma ..... *T. schoenobii* Ferriere

– Clava (excluding spicula) distinctly longer than F2+F3; body mostly black or dark brown, without metallic reflections; other characters variable 6

6. Mesoscutum with 4 pairs of adnotaular setae on either side; speculum closed behind by cubital line of setae; metasoma a little longer than combined length of (or as long as) head + mesosoma; hind coxa black; hind femur brown with apex paler; hind tibia pale yellow with a brown narrow band in middle .. *T. baricatus* Narendran sp. nov.

– Mesoscutum with 2 or 3 adnotaular setae on either side; speculum open behind; metasoma shorter than head + mesosoma; other characters partly or completely different 7

7. Mesoscutum with 3 adnotaular setae on either side; metasoma with a distinct yellow petiole (petiole 1.2× as wide as long); legs yellow with fore coxa brown ..... *T. tanus* Narendran sp. nov.

– Mesoscutum with 2 adnotaular setae on either side; metasoma with a shorter black petiole (petiole 3× as wide as long); legs pale yellow with fore femur pale brown except paler apex, hind coxa dark brown with pale apex ..... *T. wakicus* Narendran sp. nov.

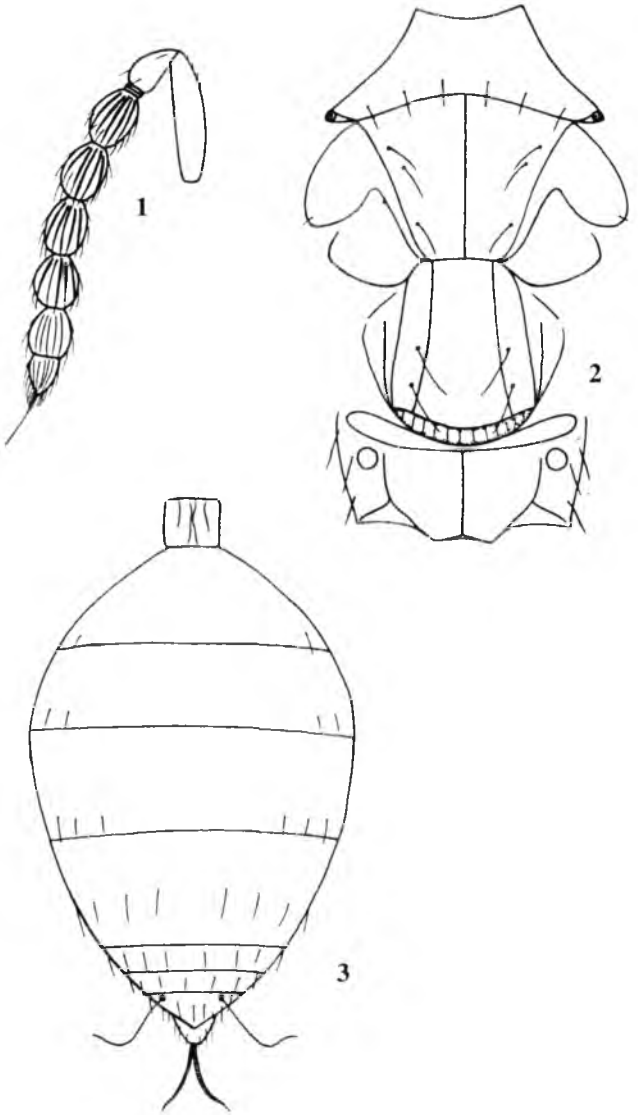
1. *Tetrastichus tanus* Narendran sp. nov. (Figs. 1–3)

Female

Length 1.4 mm. Dark brown with following parts as follows: eye and ocelli pale reflecting yellow, antenna brown with scape pale yellow; tegula pale yellow; legs yellow with fore coxa brown, tarsi whitish yellow with pretarsi brown; petiole yellow; wings hyaline with veins pale yellow with borders brown, pilosity of wings brown.

Head

Width in anterior view 1.25× its length (excluding mandibles) in dorsal view 5.4× its median length, 2.71× its maximum length; temples moderately narrow; tentorial pits relatively large; lower clypeal margin bilobed; mandibles with an outer falcate tooth; scrobe shallow, margins indistinct; frontofacial sulcus not divergent dorsally; eye pilose, eye height in profile 2x length of malar space; malar sulcus straight, without a basal fovea; occiput not margined; POL 2.33× OOL; setae on vertex relatively long, nearly as long as OD. Antennal toruli situated at level of lower margin of eye. Antennal formula 11233, flagellum with one row of long sensillae on each segment, densely pubescent with semi-erect setae; apex of clava with a spicula and seta, length of seta 2× length of spicula; scape not quite reaching level of vertex, 0.73× as long as eye height in profile; 2.15× as long as pedicel; F1 a little longer than pedicel (13:12); F2 a trifle shorter than F1; F3 a little shorter than F2, as wide as F2; clava 3.2× as long as wide.



FIGURES 1–3: 1. *Teterastichus tanus* Narendran sp. nov. Female Antenna. 2. *Teterastichus tanus* Narendran sp. nov. Female. Mesosoma dorsal view. 3. *Teterastichus tanus* Narendran sp. nov. Female. Metasoma dorsal view.

Mesosoma

Not flattened, pronotum relatively large, 3.05× as wide as long, reticulate, with a large projecting spiracle on either side; mesoscutum with a deep median sulcus, with

3 adnotaular setae (anterior two pairs nearer to each other than to posterior one); axillae strongly and angulately advanced; median carina of propodeum extending to anterior margin of dorsellum; propodeum finely reticulate, with an inverted 'Y' shaped paraspiracular carina on either side, spiracle relatively large, its rim fully exposed, separated from metanotum by less than half its diameter; callus with 3 setae on each side. Forewing 2× as long as wide; SMV with one dorsal seta; speculum large and open behind, basal line with only one seta; costal cell longer than MV (11:10), STV 0.4× as long as MV; PMV absent; length of marginal fringe half length of STV. Hind wing 4.1× as long as its maximum width; hind coxa moderately reticulate on dorsal side; midtibial spur 0.88× as long as metatarsus.

Metasoma

With distinct petiole, width of petiole 1.2× its length, with longitudinal weak striate reticulations; metasoma a little longer than mesosoma (30:25), a little shorter than combined length of head + mesosoma (30:34); hypopygium extending well beyond middle; one cercal seta on either side longer than others; ovipositor extending well beyond apex of metasoma.

Male

Unknown.

Host

Unknown.

Holotype

Female. BORNEO, Sarawak, SW Gunung Buda 64 Km S of Limbang (4°12′ N 114°36′ E), 26.xi.1996, Coll. S. L. Heydon & S. Fung (UCDC).

Paratype

1 Female with data same as that of holotype.

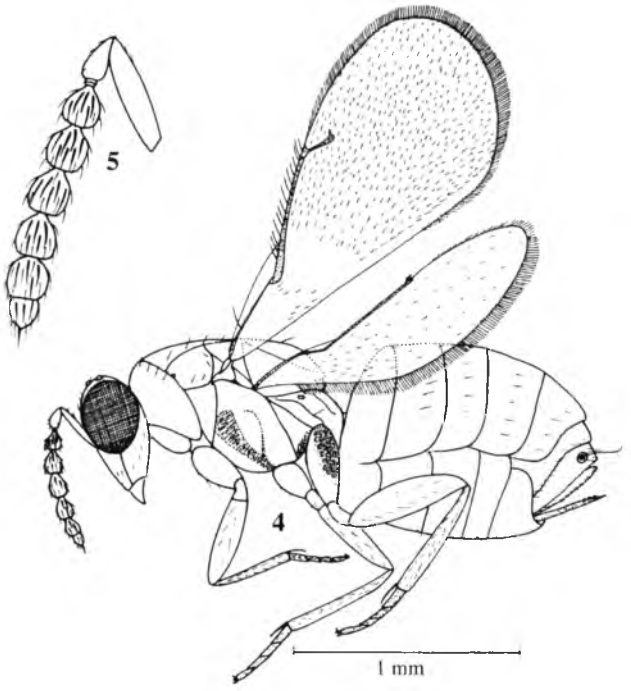
Etymology

Species name is arbitrary combination of letters.

Remarks

This new species resembles *T. lankicus* Narendran and *T. abatus* Narendran (Narendran, 2005a,b) in having relatively large pronotum with projecting spiracles on either side and in having claval spine as long as 2× length of claval speculum. However, it differs from them in the following features:

This new species differs from *T. lankicus* Narendran in having: (1) Forewing with speculum large and open behind (in *T. lankicus* speculum smaller & closed behind by cubital line of setae); (2) height of eye in profile 2× MS (in *T. lankicus* height of eye in profile 1.3× MS); (3) POL 2.33× OOL (in *T. lankicus* POL 1.71× OOL); (4) F1 distinctly longer than pedicel (in *T. lankicus* F1 not longer than pedicel); (5) F3 not transverse (in *T. lankicus* F3 distinctly transverse); (6) petiole distinct and 1.2× as wide as long (in *T. lankicus* petiole not quite distinct and not as in *T. tanus*).



FIGURES 4–5: 4. *Teterastichus baricatus* Narendran sp. nov. Female. Body profile. 5. *Teterastichus baricatus* Narendran sp. nov. Female. Antenna.

T. abatus Narendran differs from *T. tanus* sp. nov. in having: (1) 4 pairs of adnotaular setae on mesoscutum; (2) speculum closed behind by cubital line of setae; (3) eye bare; (4) costal cell of forewing shorter than MV; (5) POL 1.63x OOL; (6) hind coxa black and (7) vertex with shorter setae.

2. *Tetrastichus baricatus* Narendran sp. nov. (Figs. 4–5)

Female

Length 2.48 mm. Head and mesosoma black with following parts as follows: eye and ocelli pale yellowish white (reflecting); antenna brown with scape pale white; mandible pale yellow with teeth brown; fore and mid coxae brown; fore and mid femora brown with apices paler; fore tibia and tarsi pale yellow; mid tibia pale yellow with slight brownish tinge in the middle; mid tarsi pale yellow; hind coxa black, femur brown with apex paler; hind tibia pale yellow with a brown narrow band in the middle, tarsi pale yellow, all pretarsi dark brown. Wings hyaline, veins pale yellow with margins brown, pilosity of wings pale brown.

Head

Width in anterior view 1.33× its length, in dorsal view 3.83× as wide as its median length, 2.56× as wide as its maximum length; vertex with setae as long as or a trifle longer than OD; temples moderately narrow; lower clypeal margin bilobed; mandibles with outer falcate tooth; frontofacial sulcus not divergent dorsally; eye pilose, eye height in profile 2.11× MS; MS straight without a basal fovea; POL 1.5× OOL, OOL equal to OD. Antennal toruli situated at level of ventral ocular line; antennal formula 11233; flagellum with 2 irregular rows of sensillae on each segment, closely pubescent with semierect setae, apex of clava with a spicula and seta; length of seta 2× length of spicula; scape not quite reaching level of vertex, 0.74× as long as eye height in profile, 2.5× as long as pedicel; F1 distinctly shorter than pedicel (11:13); F2 a little longer than F1 (13:11); F3 as long as F2; clava 2.9× as long as wide (excluding spicula).

Mesosoma

Not flattened, pronotum 3.54× as broad as its maximum length in dorsal view, reticulate, with spiracle slightly projecting on either side; mesoscutum with a deep MS on posterior half, indistinct on anterior half, with 4 pairs of adnotaular setae; median carina of propodeum extending to anterior margin of dorsellum; propodeum finely reticulate, with an inverted 'Y' shaped paraspiracular carina on either side; spiracle large, rim exposed, separated from metanotum by half its diameter; callus with 3 setae on either side. Forewing about 2× as long as broad; SMV with one dorsal seta; speculum closed behind by cubital line of setae; costal cell longer than MV; STV 0.35× as long as MV; PMV absent; marginal fringe of forewing half as long as STV. Hind wing 3.5× as long as wide (including marginal fringe); hind coxa distinctly and coarsely rugose reticulate, on dorsal side; midtibial spur 0.88× length of metatarsus.

Metasoma

With a short black petiole, 2× as wide as long, hardly visible in side view, distinctly longer than mesosoma (74:60), a little longer than combined length of head + mesosoma (74:72); hypopygium reaching far beyond middle of gaster.

Male

Unknown.

Host

Unknown.

Holotype

Female. BORNEO, Sarawak, SW Gunung Buda 64 Km S of Limbang (4°13′ N 114°56′ E), 16-21.xi.1996, Coll. S. L. Heydon & S. Fung (UCDC).

Paratypes

3 Females with data same as that of holotype.

Etymology

Species name is arbitrary combination of letters.

Remarks

This new species comes near *T. tanus* Narendran sp. nov. in general features but differs from it in having: (1) mesoscutum with 4 adnotaular setae (in *T. tanus* mesoscutum with 3 adnotaular setae); (2) hind coxa black (in *T. tanus* hind coxa yellow); (3) F1 distinctly shorter than pedicel (F1 longer than pedicel in *T. tanus*); (4) speculum closed behind (in *T. tanus* speculum open behind) and in many other features.

This new species differs from *T. abatus* Narendran in having: (1) F3 as long as F2 (F3 shorter than F2 in *T. abatus*); (2) costal cell longer than MV (shorter than MV in *T. abatus*); (3) SMV with one dorsal seta (SMV with 2 dorsal setae in *T. abatus*); (4) head width in dorsal view 3.83× as wide as its maximum width (in *T. abatus* head width 2.5× as wide as its maximum width) and (5) Hindwing 3.5× as long as wide including marginal fringes (in *T. abatus* hind wing 6.86× as long as wide including marginal fringes).

3. *Tetrastichus wakicus* Narendran sp. nov. (Figs. 6–7)

Female

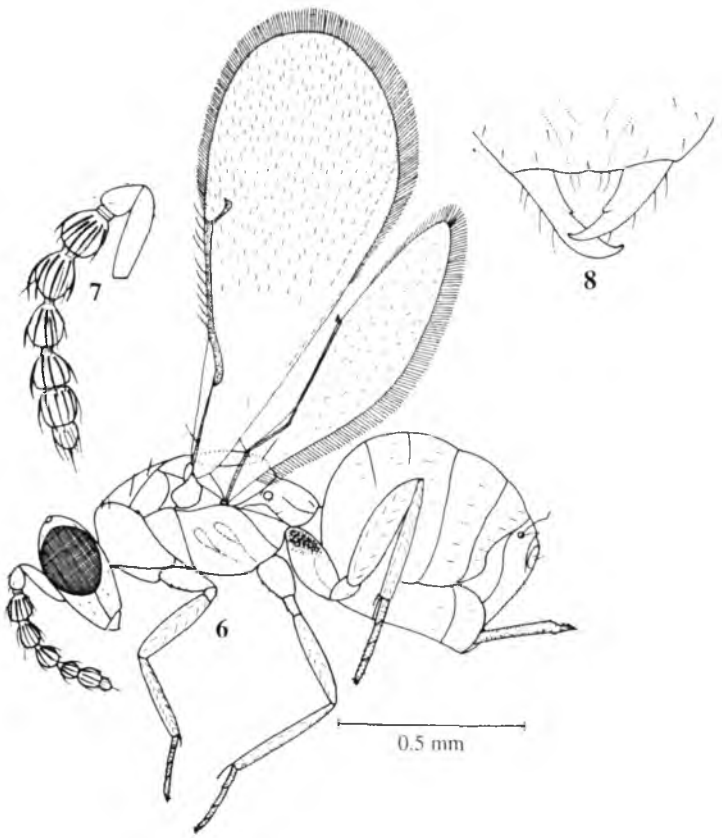
Length 1.35 mm. Dark brown with following parts as follows: eye pale yellow; ocelli reflecting yellow; antenna brown with scape paler; tegula pale brown; legs pale yellow with forecoxa, fore femora (except paler apex) pale brown, hind coxa dark brown with paler apex. Wings hyaline with veins pale yellow (margins of veins brown), pilosity of wing pale yellow.

Head

Width in anterior view 1.29× its length, in dorsal view 4.75× as wide as its median length and 2.71× as wide as its maximum length; vertex with relatively long setae, longer than OD; temples a little narrow; lower clypeal margin slightly bilobed; mandibles bidentate with moderately sized outer falcate tooth; frontofacial sulcus not divergent dorsally; eye pilose, its height in profile 2.11× as long as MS; POL 2.33× OOL; OOL equal to OD; antennal toruli situated at ventral ocular line; antennal formula 11233, flagellum with single row of long sensillae on each segment; apex of clava with a spicula and seta; seta as long as spicula; scape not reaching front ocellus, 0.84× height of eye in profile; F1 a little shorter than pedicel; F2 as long as F1; F3 a little shorter than F2 (11.5:12); clava 3× as long as wide (excluding spicula); a little longer than scape, as long as combined length of F2+F3.

Mesosoma

Pronotum 4× as wide as its median length, 2.5× as wide as its maximum dorsal length, with spiracle slightly projecting on sides; mesoscutum with a median groove (ML) distinct except at anterior one-third, with 2 adnotaular setae on either side; midlobe of mesoscutum 2.16× as long as its posterior width; median carina of propodeum extending to anterior margin of dorsellum; propodeum with distinct inverted 'Y' shaped paraspiracular carina on either side; spiracle large, rim exposed, separated from metanotum by half its diameter, callus with 3 setae on either side.



FIGURES 6–8: 6. *Teterastichus wakicus* Narendran sp. nov. Female. Body profile. 7. *Teterastichus wakicus* Narendran sp. nov. Female. Antenna. 8. *Teterastichus vadanatus* Narendran. Female Lower head with mandibles.

Forewing (including fringe) 2.20× as long as its maximum width; SMV with one dorsal seta; speculum large, open behind; costal cell a little longer than MV; STV 0.22× as long as MV; PMV absent; marginal fringe of forewing almost as long as STV; hindwing 3.7× as long as wide (including marginal fringe); hind coxa distinctly reticulate dorsally; midtibial spur as long as metatarsus. Enclosed space of SMG 2.75× as long as its width.

Metasoma

With extremely short transverse petiole, 3× as wide as long, not visible in side view; metasoma as long as mesosoma, distinctly shorter than head + mesosoma combined; hypopygium reaching beyond middle of gaster.

Male

Unknown.

Host

Unknown.

Holotype

Female. BORNEO, Sarawak, SW Gunung Buda 64 Km S. Limbang 4°13′ N 114°56′ E, 8-15.xi.1996, Coll. S. L. Heydon & S. Fung (UCDC).

Paratypes

2 Females with data same as that of holotype except dates of collection 26.xi.1996, 5.xi.1996.

Etymology

Species name is arbitrary combination of letters.

Remarks

This new species resembles *T. baricatus* Narendran sp. nov. in general appearance but differs from it in having: (1) mesoscutum with 2 adnotaular setae on each side (in *T. baricatus* mesoscutum with 4 pairs of adnotaular setae); (2) flagellum with single row of sensillae on each segment (with 2 rows of sensillae in *T. baricatus*); (3) STV 0.22× as long as MV (in *T. baricatus* STV 0.35× as long as MV); (4) metasoma as long as mesosoma (in *T. baricatus* metasoma distinctly longer than mesosoma).

4. *Tetrastichus* (*Neostichus subg.nom. nov.*) *vadanatus* Narendran (Fig. 8)

Tetrastichus (*Neotetrastichus*) *vadanatus* Narendran (in Narendran *et al.*, 2004: 118–119. Female. Borneo (UCDC) (Preoccupied by *Neotetrastichus* Perkins 1912).

Since the subgenus name *Neotetrastichus* Narendran (2004) is preoccupied by *Neotetrastichus* Perkins 1912:14, a new name *Neostichus* is hereby proposed as a replacement name for *Neotetrastichus* Narendran (2004).

This species can be easily identified by its subgeneric character of unusually large falcate outer teeth of mandibles with a tubercle like inner tooth on either mandible and other features mentioned in the original description. Only further studies may reveal whether this subgenus deserve a separate generic status.

Material examined

Holotype (UCDC)

Type locality

BORNEO, Sarawak, SW Gunung Buda, 64 Km S. Limbang (4°13′ N 114°56′ E).

5. *Tetrastichus abatus* Narendran

Tetrastichus abatus Narendran, 2005a,b: 37-41. Female Borneo (UCDC)

The original description and key given above are sufficient for easy identification of this species. The species shows some features of the genus *Aceratoneuromyia* Girault such as long seta on apical spicule of antenna, in the nature of spiracle at apex of gaster and in the sculpture of mesoscutum and scutellum.

Material examined

Holotype Female (UCDC).

Type locality

BORNEO, Sarawak, SW Gunung Buda, 64 Km S. Limbang 4°13′ N 114°56′ E.

6. *Tetrastichus bellus* Narendran

Tetrastichus bellus Narendran (in Narendran *et al.*, 2006). Female, Borneo (UCDC)

After describing the species from Borneo, I discovered some females which emerged from unidentified leaf galls of *Ficus bengalensis* from New Delhi, Manjeri (Kerala) and Kalipoyka (Near Calicut). These specimens clearly agree with the type but have slightly more yellowish tinge with a dark mark on posterior part of gaster.

Material examined

Holotype (UCDC) and 1 Female, INDIA, New Delhi, 23.ix.2005, M. Sheeba (DZUC); 3 Females, Kerala, Kalipoyka (near Calicut) 22.iv.2004, M. Sheeba and 5 Females, Kerala, Manjeri, 20.iii.2004, M. Sheeba.

7. *Tetrastichus howardii* (Olliff)

Euplectrus howardii Olliff, 1893: 381–382 Female (AMS).

Tetrastichus howardii Olliff, Boucek (1988) transferred to *Tetrastichus*.

[See Boucek, 1988 and Hayat and Shahi, 2004 for extralimital synonyms]

The original description and redescription by Rohwer (1921), Mani & Kurian (1953), Mani (1989), Kurian (1952), Khan *et. al.*. (1986), Khan & Shafee (1988) are enough for identification of this species. Boucek (1988) provided figures of body of female and male antenna.

Host

In Sarawak this species is parasitic on Rice stem borers (Rotschild, 1971). The extralimital hosts include several species of Lepidoptera.

Type locality

New South Wales, Australia.

Distribution

From Mauritius, Pakistan to Taiwan, to Papua New Guinea & eastern Australia (Boucek, 1988).

Material examined

Earlier this species was reported from Sarawak (Anonymous, 1966, 1967; Rothschild, 1971; Noyes, 2006) (I have also seen one specimen collected by Steven L. Heydon from Sarawak in his large collection of Eulophids from Borneo). Extralimital specimens examined: 21 Females, INDIA, Kerala, Kasaragod, 15.xi.1998.

8. *Tetrastichus schoenobii* Ferriere

Tetrastichus schoenobii Ferriere, 1931:22:290. Ferriere (BMNH).

The original description by Ferriere and the key given above are sufficient for identification of this species.

Host

Eggs of *Scirpophaga incertulus* (Walker) (Lepidoptera: Pyralidae)

Type locality

Malaysia, Setapak.

Distribution

India, Sri Lanka, Bangladesh, China, Tailand, Malaysia& Borneo.

Material examined

(No material from Borneo is studied. The earlier published records (Anonymous, 1966, 1967; Rothschild, 1971; Noyes, 2006 reveals the presence of this species in Borneo). Extralimital specimens examined: 11 Females, INDIA, Kerala, Calicut Dt., Nanminda, 30.viii. 2002, 7.xii.2003, 2.11.2004, 14.ii.2004, Coll. T. C. Narendran & Party (DZUC).

Abbreviations

F1-F3 = funicular segments; ML = median mesoscutal line or sulcus; MS = malar sulcus; MV = marginal vein; OD = ocellar diameter; OOL = ocellocular line; PMV = postmarginal; vein; POL = postocellar line; SLG = sublateral grooves of scutellum; SMG = submedian grooves of scutellum; SMV = submarginal vein; STV = stigmal vein. **Depositories:** AMS = Australian Museum, Sydney, New South Wales, Australia; BMNH = The Natural History Museum, London, United Kingdom; DZUC = Department of Zoology, University of Calicut; UCDC = Bohart Museum, University of California, Davis, USA.

ACKNOWLEDGEMENTS

I thank Dr. Steven L. Heydon, Bohart Museum, University of California, Davis, U. S. A. for a loan of Eulophid specimens for studies and my students Mr. P. Girish Kumar and Miss. M. C. Jilcy for assisting me in the preparation of this paper.

REFERENCES

Anonymous, (1964) *Entomology Division Rep. Res. Branch*, Department of Agriculture: Sarawak, pp. 79–89.

Anonymous, (1967) *Entomology Division Rep. Res. Branch*, Department of Agriculture: Sarawak, pp. 126–138.

Boucek, Z. (1988) *Australasian Chalcidoidea*, CAB International: Wallingford, UK, pp. 1–832.

Ferriere, C. (1931) New Chalcidoid parasites from South Asia. *Bull. Ent. Res.* **22**: 279–295.

Graham, M. W. R. de (1991) A reclassification of European Tetrastichinae (Hymenoptera: Eulophidae) with revision of the remaining genera. *Mem. Amer. Ent. Insi.* **49**: 1–322.

Haliday, A. H. (1844) Contribution towards classification of Chalcididae. *Trans. Ent. Soc. London.* **3**: 295–301.

Hayat, M. and Shahi, M. (2004) Taxonomic notes on Indian Eulophidae (Hymenoptera: Chalcidoidea) -1. *On the types of some Tetrastichinae Oriental insects* **38**: 303–314.

Khan, M. A., Samraj, D. A. and Khan, N. (1986) *Tetrastichus davidi* sp. nov. (Hymenoptera: Eulophidae) a preliminary parasitoid associated with *Earias vitella* (Fabricius) (lepidoptera: Noctuidae) from India. *J. Bombay. Nat. Hist. Soc.* **83**: 409–411.

Khan, M. Y. and Shafee, S. A. (1988) Descriptions of eight new species of *Tetrastichus* Haliday (Hymenoptera: Eulophidae) from India. *Indian J. Syst. Ent.* **5**: 39–48.

Kurian, C. (1952) Four new species of Chalcidoidea (Parasitic Hymenoptera) from India. *Agra.univ. J. Res. (Sci.)* **1**: 55–62.

LaSalle, J. (1994) North American genera of Tetrastichinae (Hymenoptera: Eulophidae). *J. Nat. Hist.* **28**: 109–236.

Mani, M. S. (1989) The fauna of India and the adjacent countries. In: *Chalcidoidea (Hymenoptera). Part II*, Zoological Survey of India: Calcutta, 1–1633.

Mani, M. S. and Kurian, C. (1953) Descriptions and records of Chalcids (Parasitic Hymenoptera) from India. *Indian J. Ent.* **15**: 1–21.

Narendran, T. C. (2005a) On a new genus and two new species of Eulophidae (Hymenoptera: Chalcidoidea) from Oriental region. *J. Exp. Zool. India.* **8(2)**: 269–274.

Narendran, T. C. (2005b) Two new species of *Tetrastichus* Haliday (Hymenoptera: Eulophidae) displaying some characters of *Aceratoneuromyia* Girault. *Bull. Pure and Applied Sciences* **24(1)**: 37–42.

Narendran, T. C., Kishore, L., Vyjayandi, M. C., Santhosh, S., Girish Kumar, P. and Sheeba, M. (2004) A new subgenus and two new species of *Tetrastichinae* (Hymenoptera: Eulophidae) from Borneo. *Bull. Pure and Applied Sciences* **23A(2)**: 117–123.

Narendran, T. C., Girish Kumar, P. and Kishore, L. (2006) Two new species of *Tetrastichinae* (Hymenoptera: Eulophidae) from Borneo. *J. Exp. Zool. India.* **9(1)**: 33–37.

Noyes, J. S. (2006) Universal Chalcidoidea Database.`www.nhm.ac.uk.entomology/chalcidoids`.

Olliff, A. S. (1893) Report on a visit to the Clarence River district for the purpose of ascertaining the nature and extent of insect ravages in the sugar-cane crops. *Agro. Ga3.N.S.W.* **4(5)**: 373–387.

Perkins, R. C. L. (1912) Parasites of insects attacking sugarcane. *Bulletin of Hawaiian Sugar Planters Association Experiment Station(Entomology Services)* **10**: 1–27.

Rohwer, S. A. (1921) Descriptions of new Chalcidoid flies from Coimbatore, South India. *Ann. Mag. Nat. Hist.* **9(7)**: 123–135.

Rothschild, G. H. L. (1971) The biology and Ecology of Rice Stem borers in Sarawak. *Journal of Applied Ecology* **8**: 287–322.

(Received 24 April 2006; accepted 9 November 2006)

ENTOMON **31(4):** 307–313 (2006)
Article No. ent.31407

Two new species of Prostigmatid mites infesting medicinal plants in West Bengal, India

I. Roy, S. K. Gupta* and G. K. Saha†

Entomology and Wildlife Biology Research Laboratory, Department of Zoology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata- 700019, West Bengal, India
Email: gkszoo@rediffmail.com

ABSTRACT: Two new species, one each of *Exothorhis* Summers (Fam. Raphignathidae) and *Agistemus* Summers (Fam. Stigmaeidae) collected from the medicinal plants *Justicia adhatoda* L. (Acanthaceae) and *Urena lobata* L. (Malvaceae), respectively, from West Bengal, India are described.

KEYWORDS: Prostigmata, *Exothorhis*, *Agistemus*, new species, medicinal plants, *Justicia adhatoda* , *Urena lobata*

INTRODUCTION

This paper describes two new species of prostigmatid mites, one each of *Exothorhis* Summers (Fam: Raphignathidae) and *Agistemus* Summers (Fam: Stigmaeidae). Both the above genera are recorded for the first time from two common medicinal plants, viz. *Justicia adhatoda* L., (Acanthaceae) and *Urena lobata* L., (Malvaceae) from West Bengal, India. Type specimens are deposited in the Entomology and Wildlife Biology Research Laboratory, Calcutta University, which in due course will be deposited in the Zoological Survey of India, Kolkata. All the measurements are given in microns.

FAMILY 1. RAPHIGNATHIDAE Kramer

Genus: Exothorhis Summers

Exothorhis justicia sp. nov. (Figures 1–10)

Female

Body (from posterior tip to gnathosoma) 297 long and 165 wide. Palp 92 long, 4 segmented. Palp tarsus 29 long, narrow to rod-like, with almost half of the width of the

*Formerly of Zoological Survey of India, Kolkata 700053, India
†Corresponding author

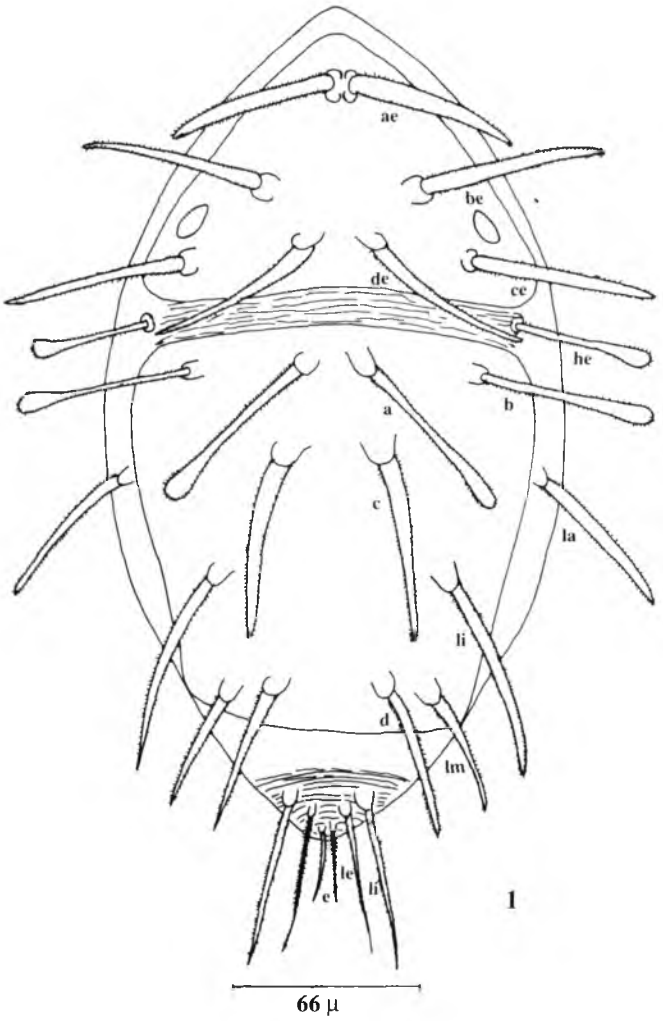
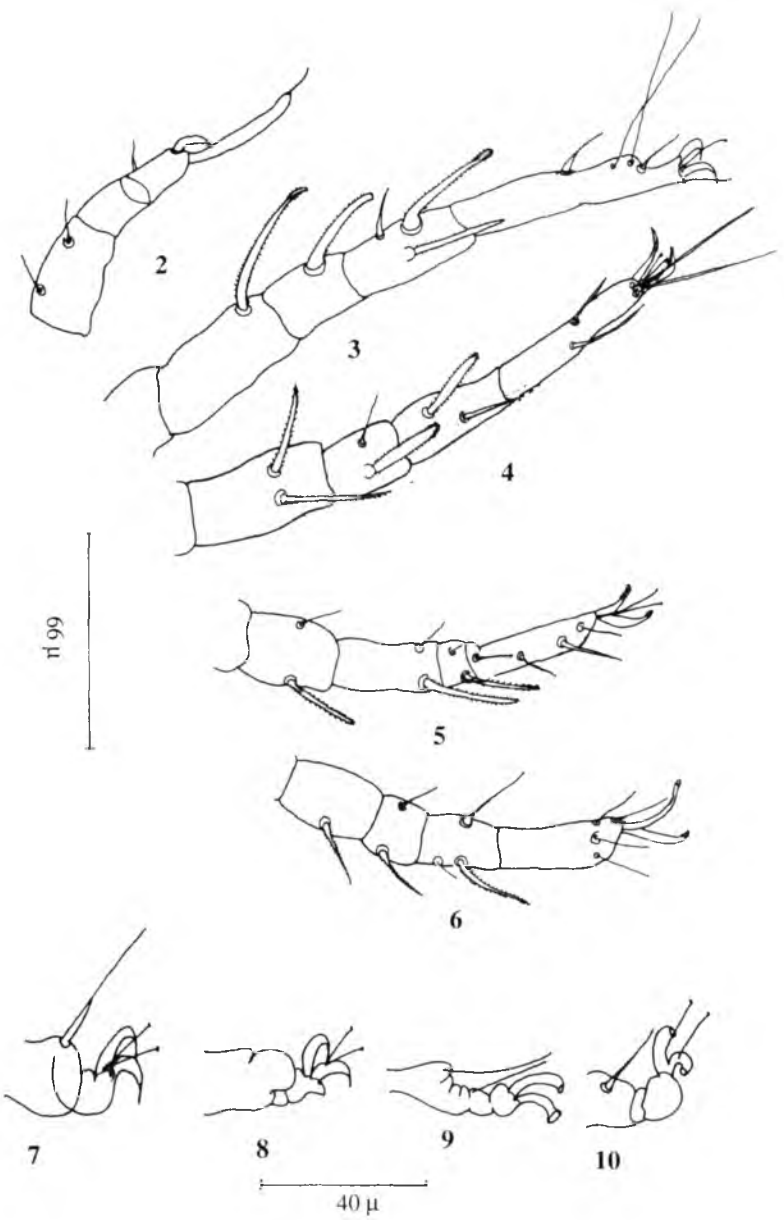


FIGURE 1. *Exothorhis justicia* sp. nov. Dorsal view.

tibia. Palp tibia with one seta. Seta on the other palp segment not discernible. Dorsal surface covered by the podonotal and opisthonotal shields with transverse striation in between. Podonotal shield with 4 pairs of long serrate, thick setae. Opisthonotal shield with 7 pairs of setae of similar nature as those of podonotal. The podonotal and opisthonotal setae much longer than the distance between their bases and those of the following setae. Seta a extends beyond the base of b and c. Humeral setae 42 long, tip slightly spatulate. Legs 4 pairs, each measuring 132. Leg-I with three macrosetae, one each on femur, genu and tibia, measuring 42, 33 and 36, respectively, all spatulate,



FIGURES 2–10: 2. *Exothorhis justicia* sp. nov. Palp. 3. *Exothorhis justicia* sp. nov. Leg I. 4. *Exothorhis justicia* sp. nov. Leg II. 5. *Exothorhis justicia* sp. nov. Leg III. 6. *Exothorhis justicia* sp. nov. Leg IV. 7. *Exothorhis justicia* sp. nov. Tarsal segment of leg I showing claw. 8. *Exothorhis justicia* sp. nov. Tarsal segment of leg II showing claw. 9. *Exothorhis justicia* sp. nov. Tarsal segment of leg III showing claw. 10. *Exothorhis justicia* sp. nov. Tarsal segment of leg IV showing claw.

tarsus I ends with two whip-like setae each measuring 50 long. The strong claws paired with tenent hairs, measurements of macrosetae on femur II—33, genu II—26, tibia II—26, femur III—20, genu III—23, tibia III—23 long, femur IV—23, genu IV—23. The 3rd and 4th legs end with peculiar shaped strong claw. Ocular body oval shaped, 13 wide. Chaetotaxy of legs and palp as illustrated. The number of setae on different leg segments are as given in the table.

Legs	Femur	Genu	Tibia	Tarsus
I	1 (spatulate, gently serrate macroseta)	1 (spatulate, gently serrate macroseta)	3 (1 spatulate, gently serrate macroseta)	4 (2 whip-like setae)
II	2 (1 long spatulate, gently serrate macroseta)	2 (1 long gently serrate macroseta)	2 (1 long spatulate, serrate macroseta)	4 (2 long whip-like setae)
III	2 (1 long spatulate macroseta)	2 (1 long spatulate serrate macroseta)	2 (1 macroseta)	4 (1 long non spatulate seta)
IV	1 (long serrate,thick seta)	2 (1 long serrate seta)	3 (1 long serrate seta)	4

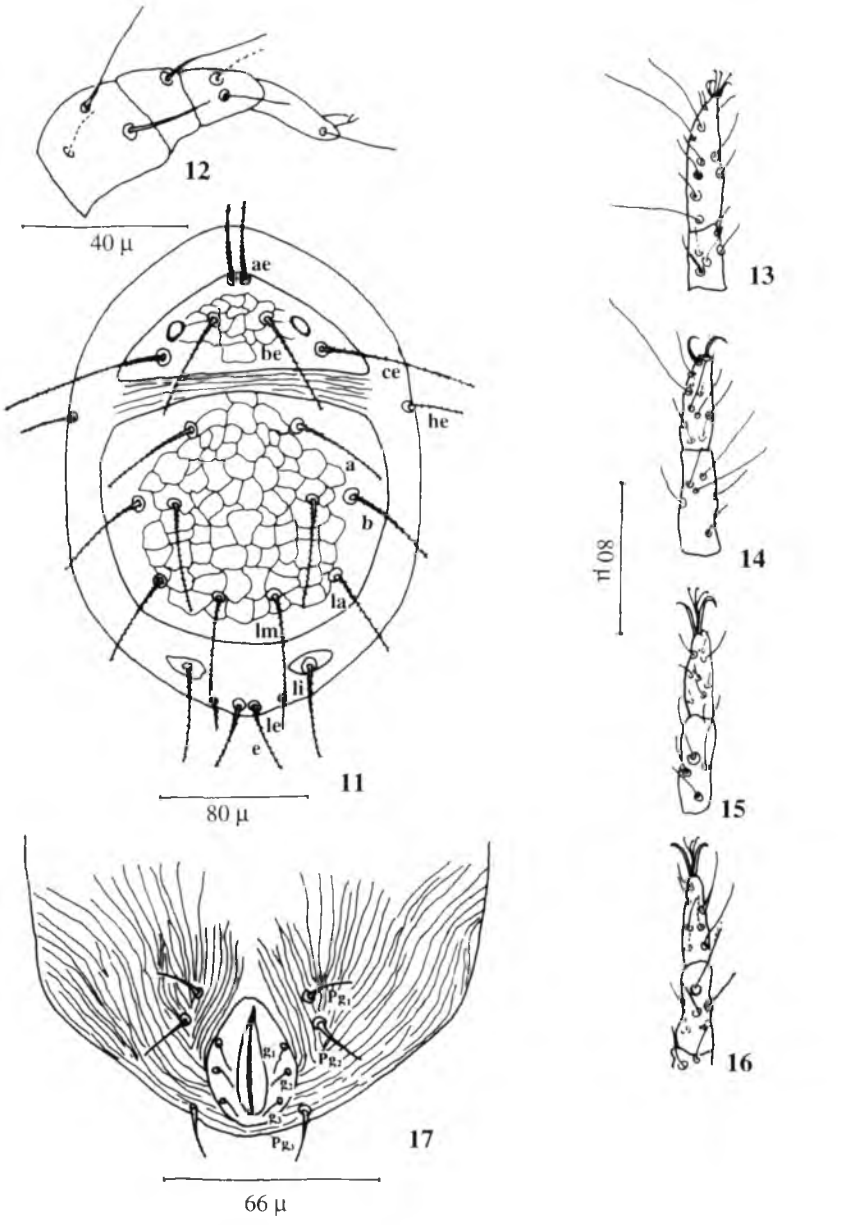
Male: Unknown
Material examined:

Holotype

Female, India: West Bengal, Experimental Garden, Department of Botany, Ballygunge Science College Campus, Kolkata, ex *Justicia adhatoda*, dated: 15-08-2005, coll. Indranil Roy.

Remarks

This new species is close to *Exothorhis nadiaensis* Chatterjee and Gupta (in Gupta, 2003) but differs from that in the following points. (i) The bases of setae a and c very close almost adjacent in *nadiaensis* but well apart in this new species: (ii) shape of hysterosomal setae differ in both the species: (iii) be/ae = 1.3 in case of *nadiaensis* but 1.1 in this new species: (iv) the dorsal body setae indistinctly plumose as compared to *nadiaensis* where it is strongly plumose: (v) the claws are somewhat spatulate in this new species but it is not so in *E. nadiaensis*.



FIGURES 11–17: 11. *Agistemus lobata* sp. nov. Dorsal view. 12. *Agistemus lobata* sp. nov. Dorsal aspect of terminal segments of palp. 13. *Agistemus lobata* sp. nov. Distal segments of leg I. 14. *Agistemus lobata* sp. nov. Distal segments of leg II. 15. *Agistemus lobata* sp. nov. Distal segments of leg III. 16. *Agistemus lobata* sp. nov. Distal segments of leg IV. 17. *Agistemus lobata* sp. nov. Venter of female opisthosoma.

FAMILY 2 : STIGMAEIDAE Oudemans

Genus Agistemus Summer

Agistemus lobata sp. nov. (Figures 11–17)

Female: Dorsum: Body from posterior tip upto base of chelicera 343 long and 293 wide. Propodosomal plate 42 long and 138 wide with polygonal reticulation and 3 pairs of setae *viz.* ae, be, ce measuring 33, 52 and 85, respectively. Post-ocular body prominent, about 26 long, 23 wide. The setae on propodosomal shield thinly serrate. ae–ae — 9, ce–ce — 82, ae/ae–ae — 4, be/be–be — 1.3, ce/ce–ce — 0.8. The median plate 115 long and 165 wide, with 5 pairs of setae. a-36, b-36, c-39, la-36, lm-39. Setae minutely serrate. a/a-a — 0.5 ; b/b-b — 0.8. Median plate with polygonal cells, c/c-c — 0.59; e-30, li-45. Area in between propodosomal and median plate with transverse striation. Paragenital setae (Pg1) –26 long. Measurement of legs: I — 172, II — 149, III — 165, IV – 198, all legs terminate with a pair of claw and tenent hairs. Dorsal most setae of tarsus I — 49 long. Chaetotaxy of legs and palp as illustrated. The number of setae on different leg segments are as given in the table.

Legs	Coxa	Tronchanter	Femur	Genu	Tibia	Tarsus
I	2	nil	5	nil	6	12
II	1	1	4	1	6	10
III	2	1	2	0	6	8
IV	2	1	2	0	6	7

Male : Unknown

Material examined

Holotype

Female: India: West Bengal, Rama Krishna Mission Ashrama campus, Narendrapur, Kolkata, ex *Urena lobata*, dated: 13-06-2005, coll. Indranil Roy.

Paratypes

2 females, same data as for holotype.

Remarks

This new species differs from *Agistemus gamblei* Gupta (1991) in the following points: (i) ae/ae-ae is 4 but in case of *A. gamblei* it is 3.6 ; (ii) setae lm and li lesser than those of *A . gamblei*; (iii) a/a-a is shorter than that of *A. gamblei*;. (iv) distance between a-b and a-ba almost equal but in *A. gamblei* it is shorter. It differs from *A. miriabilis* Chaudhri *et al.* (1974) in the following points. (i) Setae lm being longest, longer than b, but in *A. miriabilis* seta b is the longest; (ii) a/a-a is less than 0.5 but in *A. miriabilis* a/a-a is 1.3. (iii) ce less than half of a, but in *A. miriabilis* it is more than that of half of ae. Finally, it also differs from *Agistemus pinus* Hu *et al.* (1997) in relative ratios of dorsal setae as well as in lacking reticulation pattern on median plate.

ACKNOWLEDGEMENTS

The authors are grateful to the Head, Department of Zoology, University of Calcutta for providing laboratory facilities. Thanks are also due to Swami Vishwamayananda, Asst. Secretary, Ramkrishna Mission Ashram, Narendrapur and the Head, Department of Botany, University of Calcutta for kindly permitting us to carry out the work in their respective gardens. Thanks are also due to Mr. S. Podder, N. Saha, G. Aditya, S. Choudhuri and S. Nandi for technical help. Financial assistance provided by MoEF, Govt. of India is gratefully acknowledged.

REFERENCES

Chaudhri, W. M., Akbar, S. and Rasool, A. (1974) Taxonomic studies on the mites belonging to the families Tenuipalpidae, Tetranychidae, Tuckerellidae, Caligonellidae, Stigmaeidae and Phytoseiidae, Univ. Lyallpur: Pakistan, pp. 1–250.

Gupta, S. K. (1991) Studies on predatory prostigmatid mites of northeast India. *Rec. Zool. Surv. India* **88(2)**: 207–239.

Gupta, S. K. (2003) A monograph of plant inhabiting predatory mites of India. Part I: Orders. Prostigmata, Astigmata and Cryptostigmata. *Mem. Zool. Surv. India* **19**: 93–94.

Hu, S., Chen, X. and Huang, L. (1997) A new species and a new record of genus *Agistemus* from China (Acari :Stigmaeidae). *Systematic & Applied Acarology Special Publications* **1**: 1–4.

(Received 17 May 2006; accepted 2 January 2007)

ENTOMON 31(4): 315–317 (2006)
Short Communication No. ent.31408

Susceptibility status of *Culex quinquefasciatus* (Visakhapattinam strain), vector of bancroftian filariasis against two organophosphorous compounds

T. Mariappan and R. Srinivasan

Vector Control Research Centre, (Indian Council of Medical Research), Pondicherry 605006, India

ABSTRACT: The susceptibility status of *Culex quinquefasciatus* (Visakhapattinam strain, Andhra Pradesh, south India) to two organophosphorous compounds viz., fenthion and temephos which are being currently used in mosquito control programme of the Municipal Corporation of Visakhapatinam city was assessed. The LC_{50}, and LC_{90} of Fenthion function were 0.00179, 0.00722 respectively and of temephos were 0.000259 and 0.00164 respectively. Both the insecticides were sufficiently toxic to be used in mosquito control programmes at Visakhapattinam though they were in use for the past few decades.

KEYWORDS: Fenthion, temephos, *Cx. quinquefasciatus*, susceptibility

The complexity encountered in the control of vectors of public health importance using of insecticides is well known. Resistance development, prohibitive cost of insecticide and environmental hazards are the major constraints identified (Das and Rajagopalan, 1979). Synergistic effect of some of the insecticides with plant extracts was reported against *Culex quinquefasciatus* (Vanmathi and Rajkumari, 2004). The other alternative vector control measures known include biological control agents which are not readily at operational level (Das and Rajagopalan, 1981). Hence under epidemics, insecticides are indispensable and also very few chemicals coming in the market for purpose are the limited number for their circulations due to heavy investment. The extent of mosquito problem in the Municipal Corporation area of Visakhapatinam, Andra Pradesh, the steel city of India is evident from to prevalence of mosquito borne diseases there. *Cx. quinquefasciatus* (Visahkapatannam strain), the vector of bancroftian filariasis breeds in drains, canals, pits, pools, septic tanks, cement tanks, ponds, overhead tanks, wells and all other polluted water bodies in the city. Fenthion a promising organophosphorous compound is being widely used as a larvicide since 1960 and Temephos, also is being used as larvicide in less polluted water habitats in the area. Development of resistance in *Cx. quinquefasciatus* against

TABLE 1. Larval susceptibility of *Cx. quinquefasciatus* (Visakhapatinam strain) to Fenthion and Temephos

Insecticide	Hetero-geneity	Regression equation	LC_{50} mg/l	LC_{90} mg/l	Fiducial limit (lower and upper) with 90% CI
Fenthion	$X^2 = 18.46$	$Y = 10.82 + 0.92 \log X$	0.00179	0.00722	0.00598–0.00872
Temephos	$X^2 = 26.56$	$Y = 10.72 + 0.69 \log X$	0.000259	0.00164	0.00118–0.00228

certain organophosphorous compounds has been reported (WHO, 1984). However no information is available on the susceptibility of the mosquito to the above insecticides which were being used in Visakhapattinam over a period of four decades. Therefore a study was carried out to find out the current susceptibility status of the fitted population of *Cx. quinquefasciatus* in the city.

Standard procedures, recommended by World Health Organization (1975), were adopted for the studies. In each replication 25 early fourth instar larvae of *Cx. quinquefasciatus* collected from drains in different sites of the city and maintained in the laboratory were taken. Mortality was observed 24 hrs. after exposure to insecticides. The data corrected with Abbott's formula were used for estimating LC_{50} and LC_{90} values adopting probit analysis technique. Results of the analysis of the data were presented in Table 1.

The LC_{50} of fenthion obtained in this study were found to be relatively lower than the values reported from elsewhere [Cochin (0. 4132 mg/l), Guntur (0.0071 mg/l), Kolar (0.0024 mg/l), Madurai (0.005 mg/l), Pondicherry (0.02 mg/l) (Mariappan *et al.*, 1982, 1994)] and the LC_{50} of temephos also was lower than the values recorded elsewhere: Guntur (0.0022 mg/l), Kolar (0.00039 mg/l), Madurai (0.0006 mg/l), Pondicherry (0.0004 mg/l) (Mariappan *et al.*, 1982; Das and Rajagopalan, 1981).

The larvae were more susceptible to temephos than fenthion. Further the present value of fenthion is lower than the recommended target dosage of 1 mg/l in the field (WHO, 1984). Both the insecticides were still be used in control programmes to reduce the mosquito menace in the city though the insecticides were being used for decades in the area.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. P.K. Das, Director and Dr. P. Jambulingam Dy. Director, Vector Control Research Centre, Pondicherry for encouragement. The assistance rendered by Ms. R. Sundarammal, Senior Library and Information Officer is also acknowledged.

REFERENCES

Das, P. K. and Rajagopalan, P. K. (1979) Susceptibility of larvae of *Culex pipiens fatigans* (Wiedemann), *Anopheles stephensi* (Listen) and *Aedes aegypti* (Linn) to insecticides

in Pondicherry. *Indian J. Med. Res.* **70**: 412–416.
Das, P. K. and Rajagopalan, P. K. (1981) Role of simulated migration of mosquitoes in development and reversal of malathion resistance in *Culex pipiens fatigans*. *Indian J. Med. Res.* **73**: 139–143.
Mariappan, T., Reddy, C. B. S. and Das, P. K. (1982) Agricultural pesticides and their role in accentuating resistance in vectors of public health. *Proc. Sym. Vectors and vector borne diseases* 181–185.
Mariappan, T., Arunachalam, N., Somachary, N. and Panicker, K. N. (1994) Susceptibility status of *Cx. quinquefasciatus* Say, 1823 the vector of bancroftian filariasis against fenthion in Cochin, Kerala. *Proc. of Sixth Kerala Science Congress* 372–373.
Vanmathi, P. and Rajkumari, S. I. P. (2004) Efficacy of insecticides, plant extract and their synergistic activity against the filariasis vector, *Culex quinquefasciatus*. *J. Ecotoxi Environ Moni.* **14(2)**: 123–129.
World Health Organization, (1975) Instructions for determining the susceptibility on resistance of mosquito larvae to insecticides. *WHO/VBC/* **75**: 583.
World Health Organization, (1984) Chemical methods for the control of arthropod vectors and pests of public health importance, WHO. Geneva, p. 108.

(Received 17 March 2006; accepted 10 November 2006)

ENTOMON 31(4): 319–322 (2006)
Short Communication No. ent.31409

Seasonal activity of pupal parasitoid *Tetrastichus sokolowskii* (Kurdjumov) on *Plutella xylostella* (Linn.) in cabbage ecosystem

Abhishek Shukla*† and Ashok Kumar

Department of Entomology, Rajasthan college of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur 313001, Rajasthan, India

ABSTRACT: Studies were conducted on the seasonal activity of pupal parasitoid, *T. sokolowskii* on the pupae of *P. xylostella* in cabbage at Udaipur. The activitiy of *T. sokolowskii* was on the peak during 2nd and 51st standard meteorological weeks in 2000–01 and 2001–02, respectively with 50 per cent pupal parasitism. The pupal parasitoid, *T. sokolowskii* showed a positive correlation with the pupal population of *P. xylostella* during both the years of experimentation.

KEYWORDS: Diamondback moth, *Plutella xylostella*, seasonal activity, pupal parasitoid, *Tetrastichus sokolowskii*

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera : Plutellidae) is an economically important pest of cruciferous crops worldwide and particularly of cabbage (*Brasicca oleracea* var. *capitata*) (Talekar and Shelton, 1993). DBM is well-distributed, cosmopolitan pest, which thrive under extremely varied climatic conditions prevailing in different parts of India. It DBM reproduce year round in 13–14 generations in various parts of India (Jayarathnam, 1977). The larvae attack the crop from the nursery stage onwards causing upto 52 per cent loss in marketable yield of cabbage (Krishna Kumar *et al.*, 1986). Farmers rely mainly on chemical pesticides for its control resulting in the development of resistance to practically all insecticides used. The heavy use of pesticides kills the natural enemies, which play a vital role in the reduction of the DBM population and other pests.

Tetrastichus sokolowskii (Kurdjumov) (Hymenoptera: Eulophidae) a gregarious pupal parasitoid of DBM is found in subtropical countries. Results of studies conducted in various parts of the world shows that this parasitoid disrupts the pupal population of DBM in the field effectively (Alam, 1982; Forbes and Mansingh,

*Corresponding author
†Present address: Krishi Vigyan Kendra, Tankarda, Chomu, Jaipur, Rajasthan, India

TABLE 1. Seasonal activity of pupal parasitoid *Tetrastichus sokolowskii* (Kurdjumov) on diamondback moth *Plutella xylostella* (Linn.) pupae

Standard Week No.	Number of pupae collected from 100 plants		% parasitisation		Mean Temperature (°C)		Mean Relative Humidity (%)	
	2000–01	2001–02	2000–01	2001–02	2000–01	2001–02	2000–01	2001–02
36	71	104	9.8	6.7	24.20	26.50	78.5	73.50
37	94	94	5.3	7.4	25.05	26.80	65.5	74.00
38	86	112	5.8	8.9	26.00	28.00	58.0	63.00
39	53	92	11.3	9.7	26.75	27.50	61.0	52.50
40	98	107	11.2	8.4	26.75	27.85	53.0	68.00
41	62	98	3.2	6.1	27.10	27.95	51.5	69.50
42	79	89	1.2	8.9	24.10	24.55	38.5	52.50
43	89	57	10.1	7.0	24.70	24.85	40.5	47.50
44	68	61	4.4	8.1	22.65	25.05	49.5	54.00
45	90	32	—	9.3	23.35	21.80	55.0	51.50
46	51	14	1.9	14.2	22.65	20.25	62.0	58.00
47	39	22	15.3	4.5	20.50	21.10	66.0	53.50
48	9	2	—	—	17.30	17.45	66.5	56.00
49	7	7	14.2	14.2	17.85	19.90	65.5	53.50
50	7	7	14.2	-	18.40	19.25	63.5	50.50
51	5	8	—	50.0	18.05	17.55	67.5	60.00
52	3	5	—	20.0	17.45	15.70	72.5	56.00
01	3	5	—	—	16.10	15.45	70.5	59.00
02	4	33	50.0	12.1	14.70	16.80	65.5	61.00
03	3	8	—	—	16.55	16.00	60.5	61.50
04	1	16	—	12.5	14.50	14.15	58.0	60.50
05	29	35	17.2	14.2	17.55	18.25	57.0	53.00
06	27	23	11.1	17.3	17.35	14.45	54.5	59.00
07	31	31	3.2	12.9	18.40	16.60	58.0	63.00
08	32	85	9.3	14.1	21.90	20.35	44.0	57.50
09	198	34	13.1	8.8	20.30	21.55	37.0	50.50
10	217	150	7.3	9.3	20.20	21.85	31.5	48.50
11	368	112	4.3	8.9	24.10	23.10	40.0	53.50
12	211	282	4.7	28.7	25.20	26.00	37.5	47.50
13	201	90	3.9	17.7	25.35	25.50	31.0	47.00

- No parasitisation

1990). The present studies were carried out to understand the seasonal activity of *T. sokolowskii* under field conditions in Udaipur.

A survey was conducted in the unsprayed cabbage crop during 2000–01 and 2001–02 at farmers field near Udaipur. The field collections commencing from first week of August (2000–01 and 2001–02) were made at weekly interval. The collection was made during early hours of the day, mostly from 0600 to 0900 hrs. The entire field was divided into four quarters and the pupae of the pest were collected and counted regularly from 25 plants selected randomly from each quarter.

The field-collected pupae were brought to laboratory and kept in glass jars along with cabbage leaves to record the emergence of natural enemies. The data on the number of healthy and parasitized pupae were recorded to determine the per cent parasitism during different time intervals. Data on weather parameters *viz.*, mean temperature and mean relative humidity were also collected for the study period. Influence of weather factors on the pupal population of *P. xylostella* and parasitisation by *T. soklowskii* was studied by working out correlation coefficient.

The pupal parasitoid, *T. sokolowskii* were recovered from field-collected pupae of *P. xylostella* throughout the crop season in both the years of experimentation i.e. 2000–01 and 2001–02. As in the Tabal 1 the activity of *T. sokolowskii* was noted from 36th standard meteorological week during both the years and the initial parasitisation was 9.8 and 6.7 per cent, respectively. The maximum 50 per cent parasitized pupae were recovered in 2nd standard week during 2000–01 and in 51st standard week during 2001–02. The mean temperature during the peak activities of parasitoid was 14.70 and 17.55 °C, while the mean relative humidity during this period was 65.5 and 60.0 per cent, respectively. The parasitoid *T. sokolowskii* showed a significant positive correlation with pest population for values 0.790 and 0.832, while with other abiotic factors *viz.*, mean temperature and mean relative humidity no significant correlation was seen.

T. sokolowskii was reported to cause 10 per cent parasitisation in pupal population of *P. xylostella* in Florida (Ru and Workman, 1979), 67.7 to 100 per cent in Barbados (Alam, 1982), 7.1 to 10.4 per cent in Jamaica (Forbes and Mansingh, 1990), 76 to 96 per cent in Santiago Island, Cape Verse, Africa (Harten and Van Harten, 1991). The parasitoid, reduced the pest population below economic injury level in Karnataka (Nagarkatti *et al.*, 1992). Further, Lim *et al.* (1985) identified *T. sokolowskii* as major pupal parasitoid of *P. xylostella* in Cape Verde Island. It was also recorded as major mortality factor of DBM pupae in Japan (Vematsu *et al.*, 1987) and from various ecological regions of Pakistan by Musthaque (1990). In present investigation *T. sokolowskii* was recovered from the pupae of *P. xylostella* and was a key pupal mortality factor at Udaipur corroborating the findings of earlier workers.

ACKNOWLEDGEMENT

The authors are thankful to Dean, Rajasthan College of Agriculture, Udaipur for providing facilities.

REFERENCES

Alam, M. M. (1982) Cabbage pests and their natural enemies in Barbados, W.I. In: *Proceedings of 18th CFCS annual meeting, 22–28 August 1982*, Barbados, pp. 307–319.

Forbes, R. A. and Mansingh, A. (1990) Insect parasites of diamondback moth, *Plutella xylostella* (L.) and seasonal fluctuations in parasitism at three locations in Jamaica. In: *Proceedings of 24th CFCS annual meeting, 15–20 August 1988*, Jamaica, 176–192.

Harten, A. V. and Van Harten, (1991) The influence of parasitoids on the mortality of pests of horticultural crops in the Cape Verda Islands. *Journal of Applied Entomology* **11 (5)**: 521–525.

Jayarathnam, K. (1977) Studies on the population dynamics of the diamondback moth *Plutella xylostella* (Linnaeus) (Lepidoptera: Yponomeutidae) and crop loss due to the pest in cabbage. *Ph.D Thesis*, University of Agricultural Sciences, Bangalore, pp. 215.

Krishna Kumar, H. K., Srinivasan, K. and Suman, C. L. (1986) Optimum control strategy of cabbage pests from a chemical control trials. *Progressive Horticulture* **18**: 104–110.

Lim, M. L. L., Harten, A. V., Lobo, L. M. L. and Van Harten, A. (1985) Biological control of crop pests in Cape Verde. Current situation and future programmes. *Revista Investigacao Agraria Centro de Estudos Agrarios* **1**: 3–12.

Musthaque, M. (1990) Some studies on *Tetrastichus sokolowkii* Kurd. (Eulophidae: Hymenoptera), a parasitoid of diamondback moth in Pakistan. *Pakistan Journal of Zoology* **22(1)**: 37–44.

Nagarkatti, S., Jayanath, K. P., Heong, K. L., Lee, B. S., Lim, T. M., Teoh, C. H. and Ibrahim, Y. (1992) Population dynamics of major insect pests of cabbage and their natural enemies in Bangalore district (India). In: *Proceedings of the International Conference on Plant Protection in the Tropics, 1–4 March, 1982*, Kuala Lumpur, Malaysia, pp. 325–347.

Ru, N. and Workman, R. B. (1979) Seasonal abundance and parasite of the imported cabbage worm, diamondback moth and cabbage webworm in Northeast Florida. *Florida Entomologist* **62(1)**: 68–69.

Talekar, N. S. and Shelton, A. (1993) Biology, ecology and management of the diamondback moth. *Annual Review of Entomology* **38**: 275–301.

Vematsu, H., Yamashita, T. and Sakanashita, A. (1987) Parasitoids of the diamondback moth, *Plutella xylostella* L. and their seasonal incidence in Miyazaki district in the Southern part of Japan. *Proceedings of the Association for Plant Protection of Kyushu* **33**: 136–138.

(Received 2 March 2006; accepted 10 January 2007)

ENTOMON 31(4): 323–326 (2006)
Short Communication No. ent.31410

Diversity of natural enemies of *Leucinodes orbonalis* Guenee (Lepidoptera: Pyraustidae)

P. Yasodha* and N. Natarajan

Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore 641003, India
Email: entyaso2002@yahoo.com

ABSTRACT: Twelve hymenopteran parasitoids emerged from field collected *Leucinodes orbonalis*. Seven of them belonged to superfamily Chalcidoidea (*Antrocephalus mitys* Walker, *Brachymeria lasus* Walker, *Spalangia endius* Walker, *S. irregularis* Walker, *Endius* sp., *Spalangia* sp., and *Trichogramma* sp.) and five, to the superfamily Ichneumonoidea (*Bracon hebetor* Say, *Trathala flavo-orbitalis* Cameroon, *Chelonus* sp., *Phaneratoma* sp., and *Vaepellinae* sp.,). *Trichogramma* sp. was found to parasitize the field exposed eggs of *L. orbonalis*. Three entomopathogens were isolated from *L. orbonalis* larvae two bacteria *viz., Serratia marcescens* (Bizio) and *Enterobacter* sp. and one fungus, *Aspergillus ochraceous* (Kent).

KEYWORDS: Parasitoids, entomopathogens, *Leucinodes orbonalis*

Leucinodes orbonalis Guenee (Lepidoptera: Pyraustidae) is a serious pest of eggplant at both vegetative (shoot) and reproductive (fruit) stages causing significant reduction in the yield by 40 to 80 per cent (AVRDC, 2003). Numerous natural enemies of *L. orbonalis* are available in the field. Their utilization will greatly cut down the use of pesticides and help to produce healthy eggplant free of toxic residues. Hence, surveys were undertaken in eggplant fields of Coimbatore, Trichy, Cuddalore and Pudukkottai districts of Tamil Nadu during January 2003 to December 2004 at fortnightly intervals to identify and catalogue the local natural enemies by collecting the larvae and pupae of *L. orbonalis*.

At every site of survey 100 infested fruits were collected as described by Sandanayake and Edirisinghe (1992). Care was taken to collect infested eggplant fruits from fields that were free from pesticide application. Collected larvae were reared on brinjal fruits/semisynthetic diet to record the emerging parasitoids. The artificial diet was prepared as described by AVRDC (2003). Since the eggs of *L. orbonalis* were laid sparsely on the plants under the field conditions, it is very difficult to locate the

*Corresponding author

parasitized eggs. Hence, the eggs of *L. orbonalis* laid on a filter paper under laboratory condition were randomly placed periodically in the field to assess the incidence of egg parasitoids. The diseased cadavers collected under natural condition during survey were transferred in sterile petriplates and glass vials, brought to laboratory and preserved with details on host insect, stage of the host, place and date of collection. Later the specimens on isolation were examined with specific microbial infections by pathogenicity test. Fungal pathogen culture was isolated on potato dextose agar following standard mycological techniques of CMI (1983) and the bacterial cultures were isolated by nutrient agar medium (Martin, 2000). Bioassay was made on *L. orbonalis* and *Helicoverpa armigera* by taking the bacterial culture at varied periods of incubation *viz.*, 24 h, 48 h and 72 h. The bioassay was done using surface sterilized (surface sterilizing solution consisting of 250 mg of carbendazim dissolved in 500 ml of sterile water) potato disc (5 mM × 5 mM). Larval mortality was recorded every 24 h consecutively for seven days. The surviving larvae were weighed on the final day of experiment. The ratio between the weight of treated larvae and the untreated control was taken as criteria for the effect on larval development. The efficacy of *Aspergillus ochraceous* was tested against second instar *L. orbonalis*. Per cent mycosis was recorded two days after treatment.

Totally 12 species of parasitoids belonging to two superfamilies of hymenoptera *viz.*, Ichneumonoidea, and Chalcidoidea, emerged from the field collected *L. orbonalis*. Five of them *viz., Trathala flavo-orbitalis* Cameroon, *Bracon hebetor* Say, *Phaneratoma* sp. *Chelonus* sp., and *Vaepellinae* sp. belonged to Ichneumonoidea. Seven parasitoids *viz., Antrocephalus mitys* Walker, *Brachymeria lasus* Walker, *Spalangia irregularis* Walker, *S. endius* Walker, *Endius* sp., *Spalangia* sp., and *Trichogramma* sp. belonged to Chalcidoidea. All except *Trathala flavo-orbitalis* and *Pheneratoma* sp. are being reported for the first time in this study, on *L. orbonalis*. The larval pupal parasitoid, *T. flavo-orbitalis* was found occurring throughout the year, causing a maximum of 54 per cent mortality. Mortality by the other parasitoids ranged from 1.5 to 12.1 per cent.

Three pathogens were identified - two bacteria *viz.*, *Serratia marcescens* (Bizio) and *Enterobacter* sp. and a fungus *Aspergillus ochraceous* (Kent). The non sporulating bacterium, *S. marcescens* at 1/5x dilution produced a mortality of 93.22 and 92.43 per cent on *L. orboalis* and *H. armigera*. About 24 h incubation of both the bacteria (*S. marcescens* and *Enterobacter* sp.) favoured high mortality on *L. orbonalis*, while 72 h incubation was essential for both cultures against *H. armigera*. *Aspergillus ochraceous* exhibited maximum mortality of *L. orbonalis* second instar (56 %) at a concentration of 1×10^7 spores per ml.

Sixteen parasitoids, three predators, and three entomopathogens were reported from *L. orbonalis* across the world (Khorsheduzzaman *et al.*, 1998). Along with *T. flavo-orbitalis*, few other ichneumonids, *Pristomerus testaceous* Morl. (Ayyar, 1927), *Eriborus argentiopilosus* (Tewari and Sandana, 1987), *Xanthopimpla punctata* (Navasero and Calilung, 1990) and *Eriborus sinicus* (Talekar, 1995), *Diadegma apostata* (Krishnamoorthy and Mani, 1998) were also reported earlier. Occurrence

of braconids, *viz., Bracon greeni* (Venkatraman *et al.*, 1948), *Bracon chinensis* (Nair, 1967) and *Phanerotoma* (Patel *et al.*, 1977; Tewari and Moorthy, 1984) was recorded on *L. orbonalis* by previous workers. There are other parasitoids reported by earlier workers, tachnids, *Pseudoperichaeta* sp. (Patel *et al.*, 1977) and unidentified dipteran parasitoid (Singh and Singh, 2002). *S. marcescens* was reported on *L. orbonalis* (Rangarajan *et al.*, 1971). Occurrence of baculovirus on *L. orbonalis* was also reported (Tewari and Sandana, 1987).

ACKNOWLEDGEMENT

Our sincere thanks are due to Dr. T. C. Narendran, Professor, Systematic Entomology Laboratory, Department of Zoology, University of Calicut, Kerala 673635, India for identification of parasitoids. Also the Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi, India and the Institute of Microbial Technology, Sector 39A, Chandigarh 160036 are gratefully acknowledged for identifying the fungal and bacterial pathogens.

REFERENCES

AVRDC, (2003) Rearing of eggplant fruit and shoot borer: A slide set and illustrated guide. In: *AVRDC Publication No.99-486. Shanhua*, Asian Vegetable Research and Development Center: Taiwan, p. 12.

Ayyar, T. V. R. (1927) The parasitic hymenoptera of economic importance noted from South India. *Bulletin of Entomological Research* **18**: 73–78.

CMI, (1983) *Plant Pathologist's Pocket Book*, Commonwealth Mycological Institute, Oxford and IBH Publishing Co.: Calcutta, India, p. 439.

Khorsheduzzaman, A. K. M., Ali, M. I., Mannan, M. A., Ahmad, A. and Karim, M. A. (1998) Component technologies of IPM package for brinjal shoot and fruit borer for Bangladesh : A review. *Bangladesh Journal of Agricultural Research* **23**: 593–606.

Krishnamoorthy, A. and Mani, M. (1998) New record of parasitoid *Diadegma apostata* (G.) on brinjal shoot and fruit borer. *Insect Environment* **4(3)**: 87.

Martin, P. A. W. (2000) Two new bacterial pathogens of colorado potato beetle (Coleoptera: Chrysomelidae). *Journal of Economic Entomology* **97**: 774–780.

Nair, K. R. (1967) *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) as a serious pest of potato plants in Mysore State. *Indian Journal of Entomology* **29(1)**: 96–97.

Navasero, M. V. and Calilung, V. J. (1990) Biology of the egg plant fruit and shoot borer, *Leucinodes orbonalis*. Guenee (Lepidoptera: Pyralidae) in Philippines. *Philippine Entomologist* **8(2)**: 749–760.

Patel, R. C., Patel, J. C. and Patel, J. K. (1977) New records of parasites of *Leucinodes orbonalis* Guen. from Gujarat. *Indian Journal of Entomology* **33(3)**: 358.

Rangarajan, M., Srivastava, R. P. and Chakravarti, B. P. (1971) A note on the different insect host of *Serratia marcescens* Bizio. *Indian Journal of Entomology* **59(12)**: 878.

Sandanayake, M. and Edirisinghe, J. P. (1992) *Trathala flavoorbitalis*: parasitisation and development in relation to host stage attacked. *Insect Science and its Application* **3**: 287–292.

Singh, T and Singh, T. K. (2002) Natural parasites and extent of parasitism to shoot and fruit borer (*Leucinodes orbonalis*) of brinjal (*Solanum melongena*) at medium high attitude hills of Meghalaya. *Indian Journal of Entomology* **64(2)**: 222–226.

Talekar, N. S. (1995) *AVRDC Report.* Integrated insect and disease management (IPM) for environment - friendly production of safe vegetables. In: *Publication No. 00-505 Shanhua*, Asian Vegetable Research and Development Center: Taiwan, p. 16.

Tewari, G. C. and Moorthy, D. N. K. (1984) New records of two parasites of brinjal shoots and fruit borer. *Leucinodes orbonalis Guenee Entomon* **9(1)**: 63–64.

Tewari, G. C. and Sandana, H. R. (1987) *Eriborus argenteopilosus* (Caweras) a new parasite of *Leucinodes orbonalis. Guenee Entomon* **12(3)**: 227–228.

Venkatraman, T. B., Gupta, S. N. and Negi, P. S. (1948) Preliminary trials in the propagation of *Bracon* (Microbracon) *greeni* Ashmead on unnatural hosts. *Proceedings of the Indiana Academy of Science* **27**: 92–104.

(Received 17 April 2006; accepted 2 February 2007)

ENTOMON 31(4): 327–332 (2006)
Short Communication No. ent.31411

A new species *Elmantis domestica* from Kerala, India (Insecta: Mantodea)

M. C. Vyjayandi* and R. S. Rajeesh

Department of Zoology, Providence Women's College, Calicut, Kerala 673009, India
Email: vyji@rediffmail.com

ABSTRACT: A new species of *Elmantis domestica* of Mantodea from Kerala is described and illustrated. This species is closely allied to *E. trincomaliae* (Saussure)

KEYWORDS: Mantodea, *Elmantis domestica*, sp.nov, Kerala, India

INTRODUCTION

The genus *Elmantis* was erected by Giglio-Tos in1915, based on the type species *Gonypeta trincomaliae* Saussure (1869). Three species of this genus are so far known from world. Mukherjee *et al.*mentioned two species of *Elmantis* from India, viz *E. trincomaliae* (Saussure) and *E. nira* Mukherjee and Hazra (1983).

MATERIALS AND METHODS

The specimen was collected from house premises by hand. The observations were made by using MZ6 Leica Stereo Zoom (Switzerland) microscope .The figures were drawn using drawing tube of the same microscope.

RESULTS

Genus *Elmantis* Giglio-Tos

Elmantis Giglio-Tos, 1915. *Bull. Soc. Entomol.* Ital., 46:161. Type species: *Gonypeta trincomaliae* Saussure.

*Corresponding author

TABLE 1. Measurements (in mm) of *Elmantis domestica*

	Total length	Pronotum	Fore leg			Middle leg			Hind leg			Fore wing	Hind wing
			Coxa	Femur	Tibia	Coxa	Femur	Tibia	Coxa	Femur	Tibia		
Male	20	4.1	3.4	5.2	2.8	2.6	5.3	3.6	2.4	6.6	6.9	18	17
Female	21	5.4	4.4	6.2	3.9	2.4	5.6	3.3	3.2	7	7.3	4.5	3.4

Diagnostic characters

Vertex with a median and two lateral lobes; eyes bulging; frontal sclerite transverse, superior border arched in the middle. Pronotum flattened, bosseles obtuse. Fore legs: femora with 4 discoidal and 4 external spines, the proximal two external spines closer to each other; tibiae with 10–11 external spines. Hind metatarsals longer than rest of the segments together.

Distribution

India: Kerala, Maharastra, Karnataka, Tamil Nadu, AndhraPradesh; Sri Lanka.

KEY TO SPECIES OF *ELMANTIS*

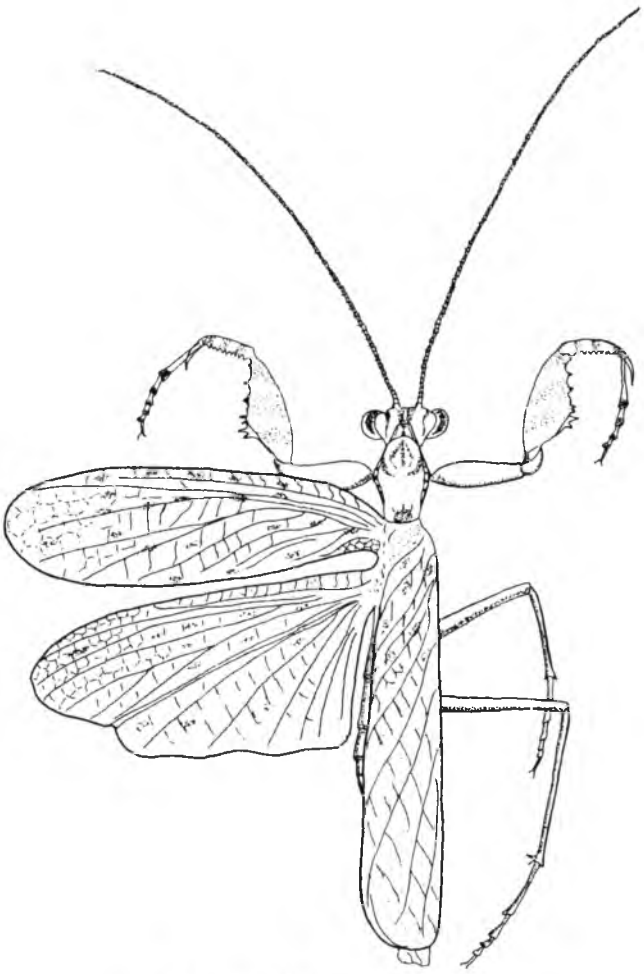
1. Fore tibia with 10 external spines 2
– Fore tibia with 11 external spines ..... *E. nira* Mukherjee and Hazra , 1983.
2. Forewing of male parallel sided and narrow, not dilated towards end ..... *E. trincomaliae* (Saussure, 1869).
– Forewing of male dialated towards end 3
3. Pronotum pointed at supra coxal dialation ..... *E. lata* Giglio-tos 1915
– Pronotum not pointed at supra coxal dialation ..... *E. domestica.* sp.nov

Elmantis domestica sp. nov

Holotype : Male: Length 20 mm

Description of male: Earth brown with faint brown dots all over the body. **Head** (Fig. 1 and 2): vertex blackish brown, lateral lobe with brown patches; frontal sclerite dark brown; eyes brown; antenna light brown; ocelli orange with black border; broadly triangular, 1.3x wider than high; vertex with two significant lateral lobes, with a median carina; eyes round; ocelli medium sized; frontal sclerite transverse, 2.6x wider than high, superior border a little arched, straight at middle, slightly elevated; antenna setaceous.

Pronotum: (Fig. 3) dorsally light brown, lateral edge with black dots, medium sized, rhomboidal, 1.5x longer than wide at supracoxal dialation, a little longer than forecoxa, supracoxal dilation well pronounced, without pointed margin; prozona with an insignificant dorsomedian groove; metazona a little dialates at base, two distinct

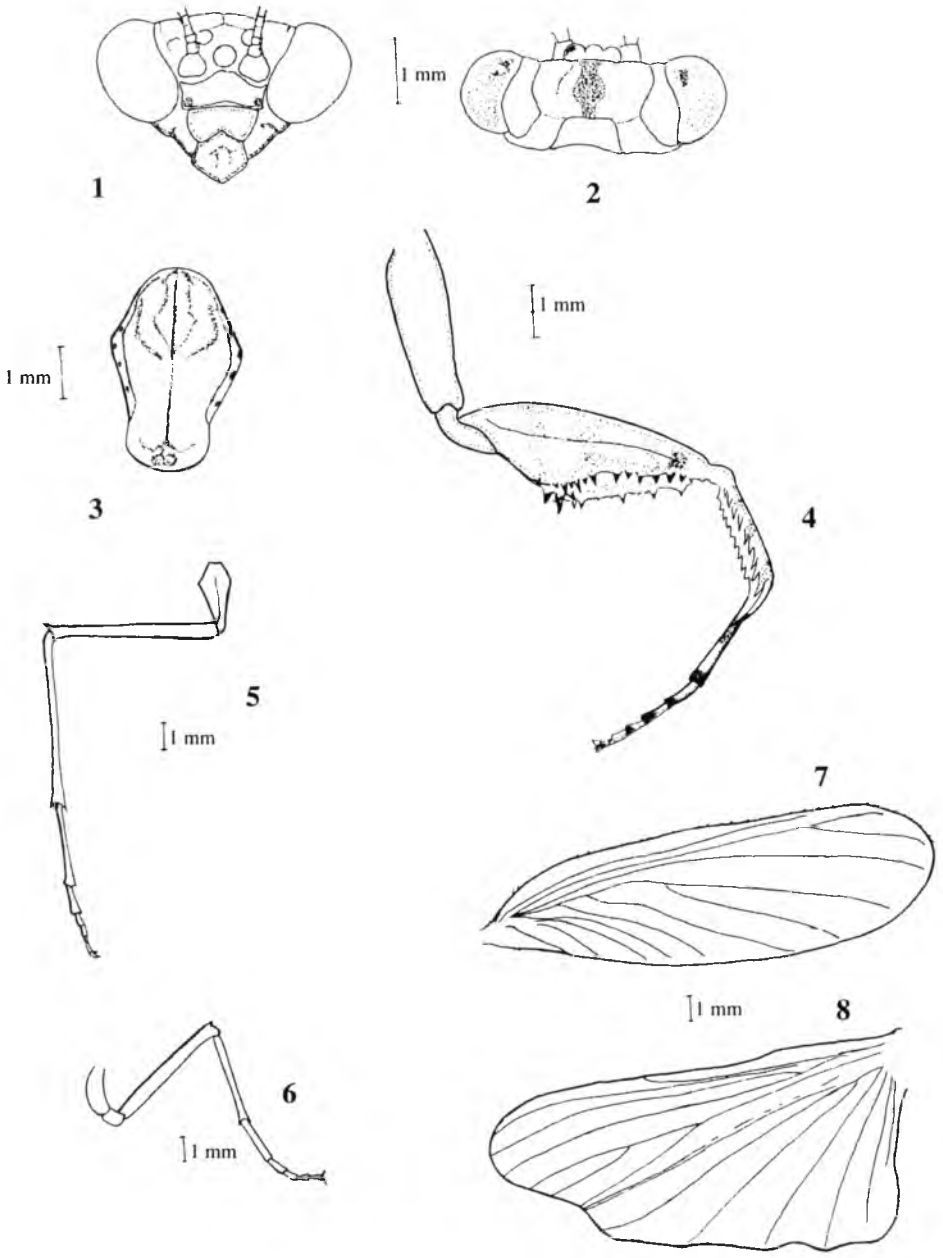


Elmantis domestica sp. nov

bosses placed at base dorsomedially, metazona 1.9 x longer than prozona, margin setaceous (Fig. 3).

Legs: Foreleg (Fig. 4), (Table 1), simple; coxa light brown with indistinct dark brown patches, both superior and inferior margins setaceous, apical lobe contiguous. Fore-femur triangular, superior border slightly arched, 1.4x longer than coxa, 1.8x longer than tibia with four external, four discoidal and twelve internal spines. Fore tibia 1.2x longer than metatarsus with ten external and ten internal spines; length of metatarsus almost same as other tarsal segments together. Mid and hind legs: mid leg (Fig. 6) shorter than hind leg (Fig. 5); femur as long as tibia; tibia more setaceous than femur; hind metatarsus a little longer than all other tarsal segments together.

Wings: hyaline, setaceous; forewing (Fig. 7) a little dialated at distal end, costal area



FIGURES 1–8: *Elmantis domestica* sp. nov.

1. Head Ventral view. 2. Head Dorsal view. 3. Pronotum. 4. Fore leg. 5. Hind leg. 6. Midleg. 7. Fore wing. Fig. 8. Hind wing.

not opaque, subcostal vein bifurcates, radius not bifurcating, media four branched, cubitus not branched, three anal veins; hind wing (Fig. 8) with sub costal vein not bifurcated, radius bifurcated, media three branched, cubitus bifurcate, anal vein four.

Metasoma: shorter than wings; supra anal plate triangular, a little broader than length; cerci short, round, ten segmented.

Description of female: Female a little more darker than male; size almost same as male; head a little broader than male; dark bands on the femur more distinct; wings highly reduced; fore wing 4.5 mm; Hind wing 3.4 mm (Table 1).

Materials examined: Holotype: Male, India, Kerala, Chelannur (Kozhikode), 26-ii-2005, Vyjayandi&party. Paratype: 1 Male&1 Female, India, Kerala, Kunnamangalam (Kozhikode)1-iii -2005, Vyjayandi& party.1 Male, India, Kerala, Pala (kottayam), 13-iii-05, Vinod.

6 Males, India, Kerala, Chelannur, 15-iii-05, 18-iii-05, Rajeesh. 1 Male, India, Kerala,

Thamarassery (Kozhikode), 15-iii-05, Rajeesh.

All the specimens are kept as dry collection in the Zoology Department of Providence Women's College Calicut, but eventually will be transfered to Zoological Survey of India Calicut.

Biology: Unknown

Etymology

The name of the species as *Elmantis domestica* refers to its common occurrence in the house premises.

Distribution: India, Kerala

DISCUSSION

The *Elmantis* sp. nov. is closely related to *Elmantis trincomaliae* in the following characters.

Frontal sclerite black, superior border arched; metazona constricted after more flattend prozona; fore leg, femur indistinctly with three brown bands, more distinct on tibia; tibiae with ten external spines.

Elmantis sp. Nov differs from *E. trincomaliae* in the following characters. In *Elmantis* sp.nov both male and female are less pigmented (while in *E. trincomaliae* male and female are darker); Pronotum not pointed at supracoxal dialation; (In *E. trincomaliae* pronotum pointed at supracoxal dialation). Fore wing, radius not bifurcated at discoidal area (radius bifurcated at discoidal area in *E. trincomaliae*); anal vein three (anal vien two in *E. trincomaliae*); hind wing cubitus not branched (cubitus bifurcated in *E. trincomaliae*); media bifurcated (media trifurcated in *E. trincomaliae*); radius trifurcated (radius bifurcated in *E. trincomaliae*).

Elmantis sp. nov. shows affinity with *E. nira* also in characters such as: fore coxae almost as long as pronotum; fore femora with a little arched margin; fore tibia with three blackish bands; fore wing light brownish, setaceous, apex slightly widened and rounded.

But it differs from *E. nira* by the following characters: Presence of ten external

spines on fore tibia (11 external spines in *E. nira)*; body shorter than *E. nira*, M 20.3mm, F 21 mm (in *E. nira*, M 27 mm).

Elmantis sp. nov has also similarity with *E. lata* in having elytra of the male long and dialated towards the end. But it differs in the body size, *E*. sp.nov being smaller than *E. lata*, body size: M 19–20 mm, F 20–21 mm. (*E. lata*, M 23 mm, F 25 mm) and also in absence of pointed supracoxal dialation of pronotum.

ACKNOWLEDGEMENTS

We are thankful to University Grant Commission for providing financial assistance.We also extend our thanks to Dr. T. C. Narendran, Prof. Emeritus, Dept. of Zoology Calicut University for his kind co-operation during the work and the authorities of Providence Women's College Calicut for providing laboratory facilities.

REFERENCES

Beier, (1956) *Verhandelingen over de natuurlijke Geschieden der Nederlandsche overzeesche Bezittingen, door de Leden der natuurkundig Commissie in Oost-Indie en andere Schrijvers-Zoologie* **67(1)**: 35.

Giglio-Tos, (1915) *Bulettino della Societa entomologica Italiana* **46**: 161. Type species *Elmantis trincomaliae*

Giglio-Tos, (1927) *Das Tierreich* **50**: 178.

Mukherjee, Hazra and Ghosh (1995) *Oriental insects* **29**: 268–269.

Mukherjee, and Hazra, (1983) *Record of Zoological Survey of India* **80**: 462.

Saussure, (1869) Mittheilungen der Schweizerischen entomologischen Gecellschaft. *Bulletin de la Societe entomologique Suisse* **3**: 63.

(Received 21 October 2005; accepted 22 May 2006)

ENTOMON 31(4): 333–338 (2006)
Short Communication No. ent.31412

Description of a new species of *Grallacheles* De Leon (Acari: Cheyletidae) from floor dust in India

S. Podder, S. K. Gupta* and G. K. Saha†

Entomology and Wildlife Biology Research Laboratory, Department of Zoology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata 700019, West Bengal, India
Email: gkszoo@rediffmail.com

ABSTRACT: One new species of *Grallacheles* De Leon (Fam: Cheyletidae), collected from house dust of Kolkata metropolis, is described here.

KEYWORDS: new species, Cheyletidae, *Grallacheles*, house dust, Kolkata, India

INTRODUCTION

This paper describes a new species belonging to genus *Grallacheles* (Family: Cheyletidae) occurring in house dust from Kolkata metropolis. The occurrence of species of this genus is being recorded for the first time from dust. All the measurements are given in microns. The holotype of the new species is presently deposited in the Entomolgy and Wildlife Biology Research Laboratory, Calcutta University, which in due course will be shifted to the National Collection of Zoological Survey of India, Kolkata.

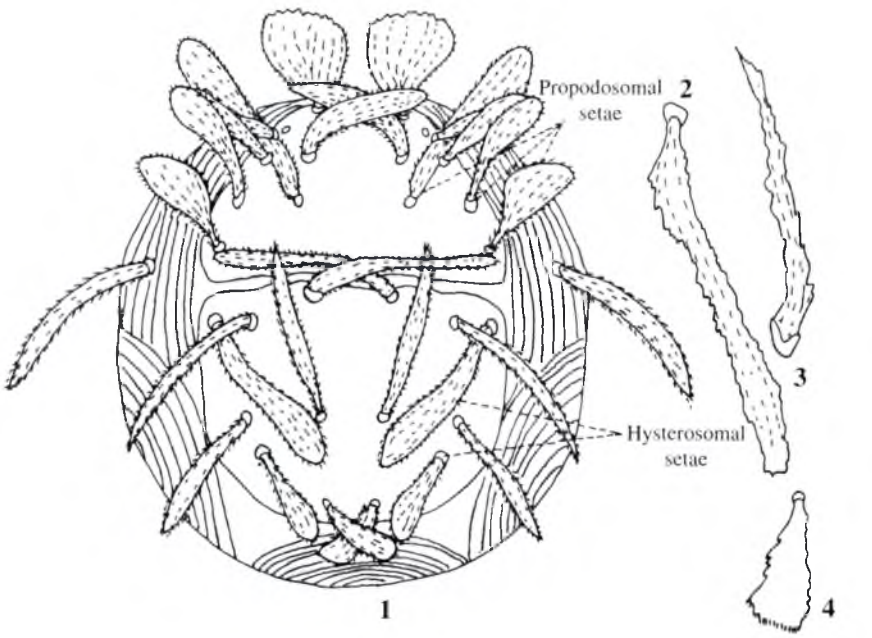
Family: Cheyletidae Leach, 1814

Genus: *Grallacheles* De Leon

Grallacheles indicus sp. nov. (Figs. 1–10)

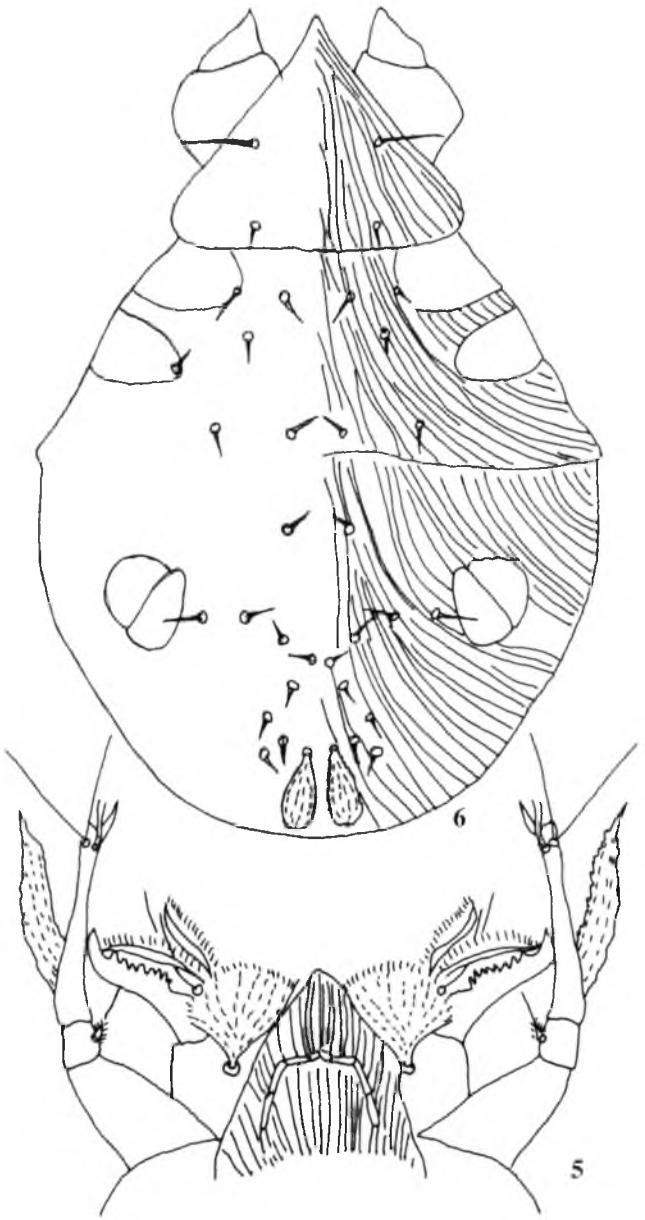
Female: Body 135 long (from posterior end upto tip of gnathosoma) and 215 wide (maximum). Propodosomal shield 99 long and 132 wide with 7 pairs of setae (5 pairs of marginal and 2 pairs of submedian), anterior most seta 59 long, fan shaped and dentate marginally with 9–10 ribs. Other propodosomal setae vary from 92–119 long, each inserted on protuberance. Figure 2. illustrated enalrged view of propodosomal

*Formerly of Zoological Survey of India, Kolkata 700053.
†Corresponding author

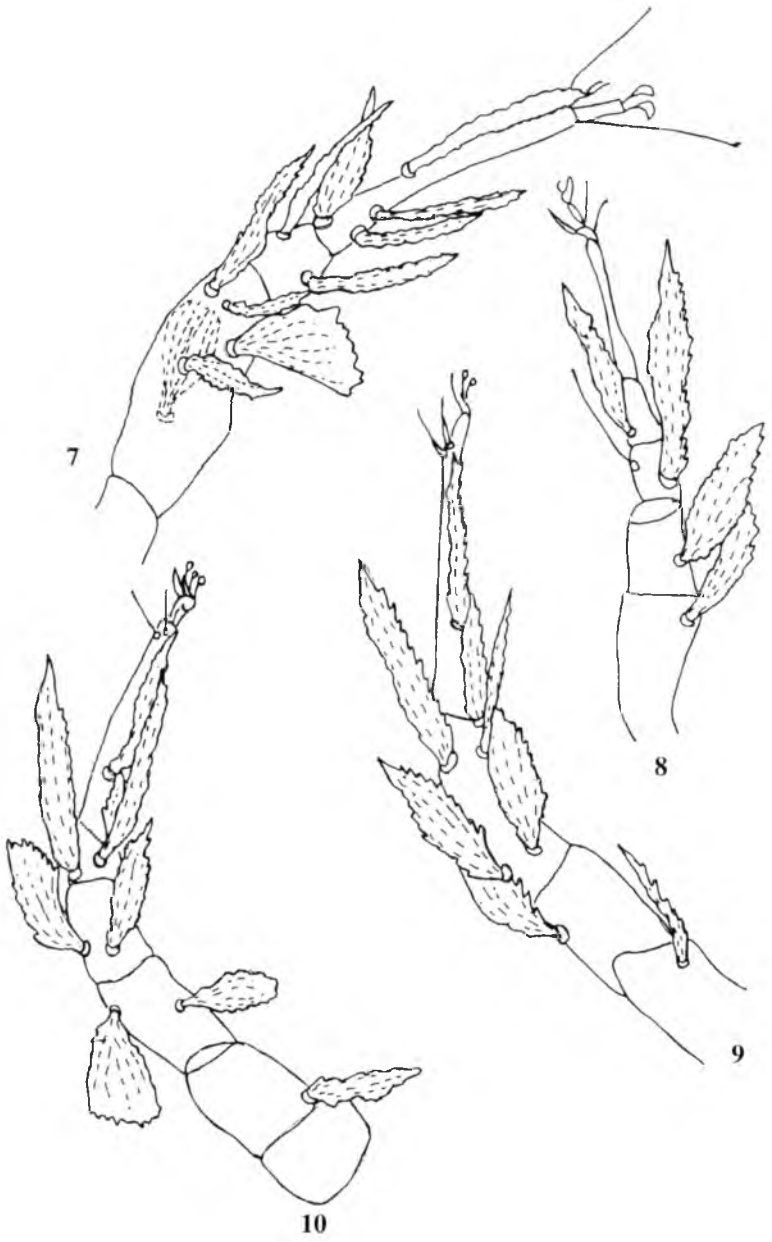


FIGURES 1–4: *Grallacheles indicus* sp. nov. (Female). 1. Dorasl surface. 2. 2nd seta on propodosomal shield. 3. 2nd seta on hysterosomal shield. 4. Poseteriormost seta.

seta. Humeral setae 132 long, same nature as those of propodosmal setae. In between propodosomal and hysterosomal shield transverse striation present and in the lateral region the longitudinal striation seen. Hysterosomal shield 149 long and 99 wide with 6 pairs of setae (4 pairs of marginal and 2 pairs of submedian), all long, thick, serrate like those on propodosomal shield except the posterior most seta which appears fan shaped like that of anterior most propodosomal seta. All setae dentate, having ribs. The length of setae on hysterosomal shield vary from 116–122. Gnathosoma mostly covered by fan-like setae of propodosomal shield. Peritreme short and 5 segmented on each side. Palp femur with 2 dorsal fan-like setae and 2 ventral fan-like setae. Palp tibial claw with 8 teeth. Palp tarsus in Fig. 5, contains 2 comb like setae with 16–17 combs and 2 sickle like setae. One pair of eyes present at the base of anterior lateral propodosomal setae, as illustrated. Striation pattern on ventral surface longitudinal at the propodosomal region, oblique laterally in the middle region, 'V' shaped medially, rounded posteriorly. Propodosomal region contains 6 pairs of ventral setae, all simple and pointed, 8–9 pairs of setae on opisthosomal region. Posteriormost anal seta fan-like with dentate margins and 5–6 ribs. Other anal setae filiform. Legs long and slender, specially tarsi, all provided with claws. Chaetotaxy of legs described below.



FIGURES 5–6: 5. Enlarged view of gnathosoma showing peritreme and palp and part of legs. 6. Ventral surface.



FIGURES 7–10: 7. Terminal segments of leg I. 8. Terminal segments of leg II. 9. Terminal segments of leg III. 10. Terminal segments of leg IV.

Legs	Tronchanter	Femur	Genu	Tibia	Tarsus
I	Nil	1D, 1V-both fan-like	2D, 1V- all fan-like	1L, long fan-like setae, 1V fan like seta	2 terminal whip-like seta, 1 long fan-like ventral seta not discernible
II	1 long fan-like seta.	1D fan-like seta	1D fan-like seta and 1V fan like seta	2D long fan-like setae, 2V long fan-like setae (not shown in the illustration due to overlapping)	Claw and tenent hairs present, 3D long terminal setae, Ventral setae not discernible
III	1 long fan-like seta	2D fan-like setae	2 long fan-like setae	2 long fan-like setae	1D fan-like seta
IV	1 long fan-like seta, terminally 3 simple setae, claw and tenent hairs present as usual	2 long fan-like setae	2D fan-like setae and 1L long fan-like setae not shown in illustration.	2 long fan-like setae and 1 pointed seta	2 long fan-like setae, 2 terminal setae and 2 claw and tenent hairs present

D- Dorsal, V- Ventral, L- Lateral

Male: Unknown

Holotype: *Female*: India: West Bengal, Kolkata, ex floor dust, 14-12-2003, deposited in Entomological collection of Zoology Department, University of Calcutta, Kolkata, India, Collector: Sanjoy Podder; Paratype ; 1 Female, data same as for holotype.

Remarks

The new species differs from *Grallacheles bakeri* De Leon (1962), in having propodosomal setae more expanded at the terminal portion (almost of uniform length in *G. bakeri*), 6 pairs of setae on hysterosomal shield (8 pairs in *G. bakeri*) and in chaetotaxy of legs which are more elongated, serrate/dentate than those on *G. bakeri*. It differs from *G. tulipi* (Gupta, 2002) in having more elongated submedian propodosomal and hysterosomal setae and in leg chaetotaxy

ACKNOWLEDGEMENT

The authors are grateful to the Head, Department of Zoology, University of Calcutta for providing laboratory facilities and also to the UGC for the financial help. Thanks are due to Mr. I. Roy, N. Saha , G. Aditya, S. Choudhuri and S. Nandi for their technical help.

REFERENCES

De Leon, D. (1962) Three new genera and seven new species of Cheyletidae (Acarina: Cheyletidae). *Fla. Ent.* **45(3)**: 129–137.

Gupta, S. K. (2002) A Monograph on Plant Inhabiting Predatory Mites of India (Part 1). Orders: Prostigmata, Astigmata and Cryptostigmata. *Mem. Zool. Surv. India.* **19(2)**: 1–83.

(Received 17 May 2006; accepted 2 December 2006)

ENTOMON **31(4):** 339–340 (2006)
Short Communication No. ent.31413

A new record of the scale *Diaspis boisduvalii* (Signoret) (Hemiptera: Diaspididae) infesting the orchid *Dendrobium nobile*

V. S. Nagrare

National Research Centre for Orchids, Pakyong 737106, Sikkim, India
Email: vishlesh2003@yahoo.co.in

ABSTRACT: Plants of *Dendrobium nobile* were severely infested (80.6%) by the scale *Diaspis boisduvalii* (Signoret) (Hemiptera: Diaspididae). Due to infestation, health of the plant was deteriorated and flower quality and quantity drastically reduced. Scales multiplied round the year but their number was low in winter. Scale infestation caused deformation of infested plant parts, yellowish spots on leaves, loss of leaves, and even death of the plant.

KEYWORDS: *Dendrobium nobile*, *Diaspis boisduvalii*

The orchid *Dendrobium nobile* which grows naturally on tree trunks in the wild flowers during March to May and is used in commercial *Dendrobium* hybrids as parents. The orchid is conserved at National Research Centre for Orchids, Pakyong, Sikkim in polyhouse made up to polycarbonate sheet, along with other orchid germplasm including *Cattleya* which were previously infested with biosduval scale *Diaspis boisduvalii* (Signoret) (Hemiptera: Diaspididae).

It was observed that *D. nobile* was severely infested by the scale *Diaspis boisduvalii*. Out of 98 plants observed 79 were infested (80.6%). Due to infestation, health of the plant deteriorated and flower quality and quantity drastically reduced. Biosduval scales multiplied round the year but their number was low in winter. Scale infestation was noticed on leaves, canes, roots and flowers and caused loss of vigor, deformation of infested plant parts, yellowish spots on leaves, loss of leaves, and even death of the plant. Gill (1997) reported that toxic saliva injected while feeding causes necrosis of tissue at the feeding site and small infestations on orchids cause extensive discoloration and large populations usually kill the host which corroborate the present findings. Since scales are spread by introduction of infested material, they are a quarantine problem on exported potted plants, cut flowers, and cut foliage.

Diaspis boisduvalii is widely distributed throughout the tropics and subtropics, and occurs under glasshouse in temperate areas (Nakahara, 1982; Danzig and Pellizzari, 1998). It has been recorded from hosts belonging to 44 genera in 15 plant families

(Davidson and Miller, 1990). Elsewhere, there are reports of Orchids like *Cattleya, Dendrobium, Epidendrum, Oncidium* and *Vanda*, as the chief host of boisduval scale (Zimmerman, 1948; Dekle, 1965). Infestation on the orchid *Dendrobium nobile* is a new report from India.

REFERENCES

Danzig, E. M. and Pellizzari, G. (1998) Diaspididae. *In*: F. Kozár (ed.), Catalogue of Palaearctic Coccoidea, Hungarian Academy of Sciences: Akaprint Nyomdaipari Kft. Budapest, Hungary, 172–370.

Davidson, J. A. and Miller, D. R. (1990) Ornamental Plants. Armoured Scale Insects, their Biology, Natural Enemies and Control, vol. 4B. Rosen, D. (Ed). Elsevier: Amsterdam, the Netherlands, 603–632.

Dekle, G. W. (1965) Arthropods of Florida. Florida Armored Scale Insects, vol. 3. Division of Plant Industry: Florida, Department of Agriculture, Gainesville, 265 pp.

Gill, R. J. (1997) The scale insects of California. Part 3. The armored scales (Homoptera: Coccoidea: Coccidae), Technical Series in Agricultural Biosystematics and Plant Pathology No. 3, California Department of Food and Agriculture: Sacramento, California, USA, 307 pp.

Nakahara, S. (1982) Checklist of the armored scales (Homoptera: Diaspididae) of the conterminous United States, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, United States Department of Agriculture: Washington, DC, USA, 110 pp.

Zimmerman, E. C. (1948) Insects of Hawaii. Homoptera: Sternorhyncha, vol. 5. University of Hawaii Press: Honolulu, 464 pp.

(Received 31 August 2006; accepted 9 February 2007)

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